1986

Improving the performance of a millimeter-wave scalar network analyzer.

Falkner, David E.

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

IMPROVING THE PERFORMANCE OF A
MILLIMETER-WAVE SCALAR NETWORK ANALYZER

by

David E. Falkner

September 1986

Thesis Advisor: Jeffrey B. Knorr

Approved for public release; distribution is unlimited.

CURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

1b. RESTRICTIVE MARKINGS

. SECURITY CLASSIFICATION AUTHORITY

). DECLASSIFICATION / DOWNGRADING SCHEDULE

3 DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release; distribution is unlimited

PERFORMING ORGANIZATION REPORT NUMBER(S)

5 MONITORING ORGANIZATION REPORT NUMBER(S)

. NAME OF PERFORMING ORGANIZATION
Naval Postgraduate School

6b OFFICE SYMBOL (If applicable)
62

7a NAME OF MONITORING ORGANIZATION
Naval Postgraduate School

. ADDRESS (City, State, and ZIP Code)
Monterey, California 93943-5000

7b. ADDRESS (City, State, and ZIP Code)
Monterey, California 93943-5000

. NAME OF FUNDING / SPONSORING ORGANIZATION

8b OFFICE SYMBOL (If applicable)

9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

. ADDRESS (City, State, and ZIP Code)

10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

TITLE (Include Security Classification)
IMPROVING THE PERFORMANCE OF A MILLIMETER-WAVE SCALAR NETWORK ANALYZER

PERSONAL AUTHOR(S)
Falkner, David E.

a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Master's Thesis	FROM ________ TO ________	1986 September	158

SUPPLEMENTARY NOTATION

COSATI CODES		
FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Measurement Techniques, Millimeter-Wave, Scalar Network Analyzer
Automated Scalar Network Analyzer

ABSTRACT (Continue on reverse if necessary and identify by block number)

This thesis descibes improvements made to an existing Millimeter-Wave Scalar Network Analyzer. The system is automated and can be used to make return and/or insertion loss measurements from 60 to 90 GHz. Measurement data can be printed or plotted on a CRT or thermal printer. Additionally, a high resolution plot with up to 4 colors can be made on an external plotter.

Other topics which are discussed include software modification, improved performance in measurement taking, dynamic range of the system, component influence on measurements and comparison of device measurements with those obtained from previous theses and manufacturer specifications.

) DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS

21 ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED

!a NAME OF RESPONSIBLE INDIVIDUAL
Jeffrey B. Knorr

22b TELEPHONE (Include Area Code)
(408) 646-2815

22c OFFICE SYMBOL
62KO

D FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

Approved for public release; distribution is unlimited.

Improving the Performance of a Millimeter-Wave Scalar Network Analyzer

by

David E. Falkner
Lieutenant, United States Navy
B.S., Purdue University, 1980

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
September 1986

ABSTRACT

This thesis descibes improvements made to an existing Millimeter-Wave Scalar Network Analyzer. The system is automated and can be used to make return and/or insertion loss measurements from 60 to 90 GHz. Measurement data can be printed or plotted on a CRT or thermal printer. Additionally, a high resolution plot with up to 4 colors can be made on an external plotter.

Other topics which are discussed include software modification, improved performance in measurement taking, dynamic range of the system, component influence on measurements and comparison of device measurements with those obtained from previous theses and manufacturer specifications.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENT

I would sincerely like to thank my thesis advisor, Professor Jeffrey B. Knorr, for his guidance and assistance throughout this thesis.

I would also like to thank my wife, Kathy, and our children for their patience and support during my tour as a student at the Naval Postgraduate School.

This thesis is dedicated to my mother and father.

I. INTRODUCTION

A. BACKGROUND

In the past few years the popularity of millimeter-wave systems has been steadily increasing. Small physical dimensions, low power requirements and large bandwidths have allowed the advent of millimeter-wave systems in many areas of electronics including communications, computer links, medicine, radar and radio astronomy.

With increased system demand comes the need to test components of millimeter-wave systems quickly and accurately. In the past computer control of a Scalar Network Analyzer was possible through the use of an Analog to Digital (A/D) converter. Such a system was developed at the Naval Postgraduate School in 1982 using the HP-9845B computer, HP-47310A A/D converter, HP-8755 Scalar Network Analyzer, HP-8620C Sweep Controller with the Hughes 47225H Full Band Sweep Plug-in and a Reflectometer Set-up using Hughes and Baytron components.[Ref. 1] This system provided a means for automated millimeter band measurements from 60 to 90 GHz. The analog main frames required extensive computer control to provide computational data and this large amount of peripheral control resulted in slower measurement times than would have been expected with an automated system.

Late model analyzer and sweeper main frames now enable direct computer control of all analyzer and sweeper

functions. Sweep data can also be internally digitized to allow full control and data passing without the need for an A/D converter. This ability to allow main frame control of functions which were originally computer controlled simplifies software commands and speeds up the measurement process. Hughes Aircraft Company now offers such a system utilizing the HP-85 computer, HP-8756 or HP-8757 Scalar Network Analyzer, HP-8350 Sweep Controller with a Hughes Full Band Millimeter-Wave Plug In and a Reflectometer Set-up using Hughes components [Ref. 2:pp. 24-25]. The software is customed to the Reflectometer components selected and the desired application.

Improvements in the Naval Postgraduate School Millimeter-Wave Scalar Network Analyzer system now offer the following features:

1. MENU DRIVEN computer control of system calibration and Device Under Test (DUT) measurements.
2. The ability to perform several DUT measurements of return and/or insertion loss from a single calibration.
3. Control of the number of data points used for the calibration/measurement from a menu choice of seven possibilities ranging from 10 data points to 401 data points.
4. All of the calibration data is taken before the lengthy calculations are started thus minimizing operator interface time.
5. DISPLAY of measurement results either in tabular or graphical form.
6. PRINTER output of measurement results in tabular or graphical form.
7. PLOTTER output using the HP-9872 series high resolution multicolor plotter.

Software modifications have also made insertion loss measurments with the "A" coupler installed faster and easier.

B. PURPOSE

This thesis investigates the performance of an automated Millimeter-Wave Scalar Network Analyzer using the following components:

1. HP-9845B Computer.
2. HP-8350B Mainframe Sweeper with the Hughes Full Band Millimeter-Wave Plug-in.
3. HP-8756 Mainframe Scalar Network Analyzer.
4. Reflectometer Setup using Hughes components.
5. HP-9872 Plotter.

The system performance will be compared with known components with attributes and deficiencies noted. Additionally the measurements obtained will also be compared with measurements obtained in previous theses and with manufacturers component specifications. The systems dynamic range will be determined and compared with the Hughes Automated Millimeter-Wave Scalar Network Analyzer.

C. RELATED WORK

Under the direction of Professor Jeffrey B. Knorr, U. S. Naval Postgraduate School, G. S. Leoussis and E. D. Gatsos developed the NPS Automated Millimeter-Wave Scalar Network Analyzer [Refs. 1,4]. Professor Knorr's development of the measurement theory and mathematical models used in the software can be found in Reference 3.

The Millimeter-Wave Scalar Network Analyzer is a waveguide based system. The system must be able to measure the incident and scattered RF power of a device under test (DUT). Performance is given in terms of the scattering parameter amplitudes which can then be used to compute the return loss and/or the insertion loss of the DUT.

In general, scattering parameters can be defined in the form:

$$S_{mn} = \left.\frac{b_m}{a_n}\right|_{a_i=0} \qquad (i \neq n) \qquad (1)$$

where S_{mn} is the complex ratio of the variable b_m of a signal (wave) emerging from port m relative to the variable a_n of a signal (wave) incident at port n. The Network Analyzer is designed to measure parameters proportional to $|b_m|$ and $|a_n|$ so that their amplitude ratio can be computed. Since this type of measurement lends itself easily to computer control and computations, typically modern systems are automated. The objective is to use the measurement system to determine the insertion loss, IL, and return loss, RL, of a DUT. For illustrative purposes, with the generic two-port device in Figure 1 placed in the forward direction (Port A driven), the return loss at Port A and the insertion loss from Port A to Port B are related to the scattering coefficients of the DUT by:

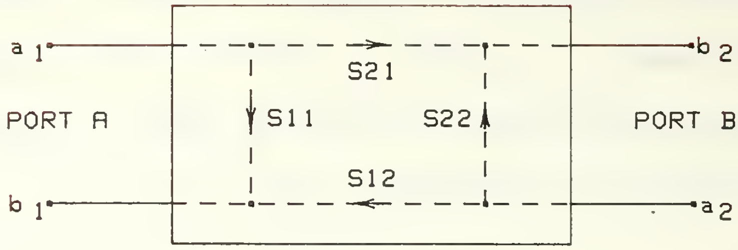
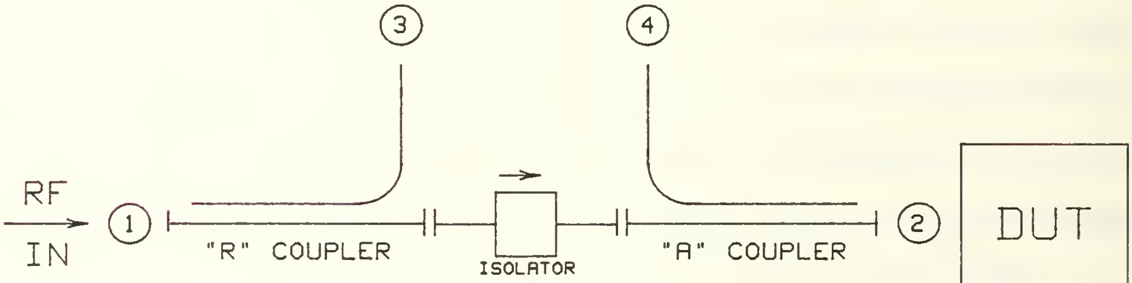
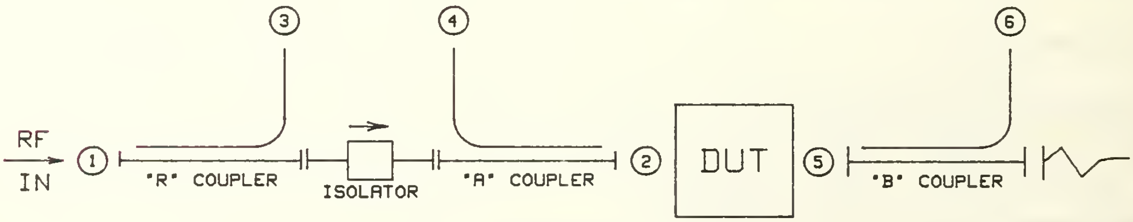


Figure 1. Scattering Parameter Signal Flow Diagram for a Two Port Network.



a. Return Loss



b. Insertion Loss

Figure 2. Basic Diagrams for Return and Insertion Loss Measurements.

$$RL_A = -10 \log_{10}|S_{11}|^2 \quad (2)$$

$$IL_{AB} = -10 \log_{10}|S_{21}|^2 \quad (3)$$

If the DUT is reversed, then the return loss at Port B and the insertion loss from Port B to Port A can be determined as follows:

$$RL_B = -10 \log_{10}|S_{22}|^2 \quad (4)$$

$$IL_{BA} = -10 \log_{10}|S_{12}|^2 \quad (5)$$

The scalar measurement system is designed to obtain the parameters which can be used to determine the magnitude of the scattering coefficients and finally the desired return and insertion losses.

Simplified diagrams of the reflectometers used for return loss measurements and insertion loss measurements are illustrated in Figures 2a and 2b respectively. The three couplers are referred to as the R, A, and B couplers since they provide samples of the incident (reference) signal, the signal scattered from Port A of the DUT, and the signal scattered from Port B of the DUT. Square-law detectors located at 3, 4, and 6 provide output voltages proportional to the RF-signal power scattered to these three ports. The return loss is determined from the ratio V_A/V_R, and the insertion loss is determined from the ratio V_B/V_R. In an ideal system, RL and IL could be determined directly from these quantities. In practice, however, these values are

corrupted by component differences and imperfections. It is necessary, therefore, to first calibrate the system and then accept some uncertainty when the measurement is taken. If the measurement uncertainties can be quantified, then some bounds of measurement uncertainty can be determined so that meaningful interpretation of the results can be made.

1. Return Loss Measurement Analysis

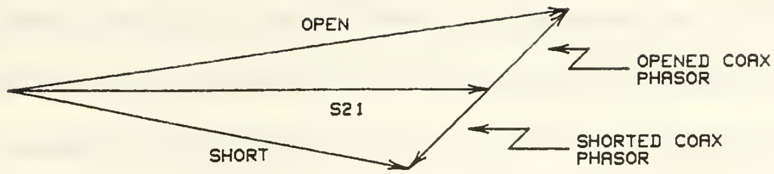
In general, the return loss from a DUT port, k, is given by:

$$RL_k = -10 \log_{10}(P_k^-/P_k^+) \tag{6}$$

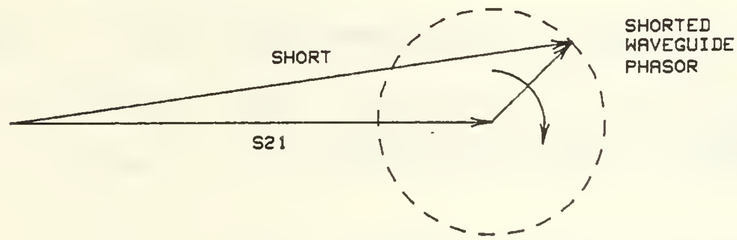
where P_k^- is the power scattered from port k, and P_k^+ is the power incident on port k. The incident and reflected powers are detected at ports R and A respectively and the detector output voltages are sent to the scalar analyzer. Referring to Figure 2a, the ratio of detector voltages may be expressed in terms of the scattering coefficients of the reflectometer bridge as:

$$(V_A/V_R) = a^2 \left| \frac{S_{41}}{S_{42}} + S_{21}(1+S_{22}\Gamma_{in})\Gamma_{in} \right|^2 \tag{7}$$

where a^2 is a constant, and Γ_{in} is the input reflection coefficient of the DUT and where it has been assumed that $|S_{22}\Gamma_{in}|<<1$. It should be recognized that $|S_{21}|\approx 1$ and that $|S_{41}/S_{42}|<<1$ will be approximately equal to the directivity



a. Coaxial Scalar Network Analyzer.



b. Waveguide Scalar Network Analyzer.

Figure 3. Phasor Diagrams for Establishing 0 dB Return-Loss Signal Level in Scalar Network Analyzers.

of the A coupler. However, the coupler directivity will always be an upper bound for $|S_{41}/S_{42}|$.

Before making a measurement, the 0 dB return loss reference level must be determined. In a coaxial scalar network system the reference value could be determined by substituting the DUT by a coaxial short followed by a coaxial open and measuring the respective return loss values. In this way the two extreme phasor components of the signal magnitude could be determined. As illustrated in Figure 3a, the 0 dB reference value could then be determined by the linear average of the shorted and open measurements.

Establishing the 0 dB return-loss reference level for a waveguide system is somewhat more involved, however,

since there is no waveguide equivalent to the open coaxial port. Equation (7) indicates that this level could be established through the use of a sliding waveguide short. In this case, $\Gamma_{in} = e^{j\phi}$ and, as the position of the short is varied, oneobtains maximum and minimum readings for each measurement frequency (see Figure 3b)

$$(V_A/V_R)^{1/2}_{\substack{cal\\max}} = a\ |S_{21}|(1+|S_{22}|) + \delta \qquad (8)$$

$$(V_A/V_R)^{1/2}_{\substack{cal\\min}} = a\ |S_{21}|(1-|S_{22}|) - \delta \qquad (9)$$

where

$$\delta = C\ |S_{41}/S_{42}| \qquad (-1 \leq C \leq +1). \qquad (10)$$

If these readings are averaged as follows:

$$(V_A/V_R)^{1/2}_{\substack{cal\\avg}} = 1/2[(V_A/V_R)^{1/2}_{\substack{cal\\max}} + (V_A/V_R)^{1/2}_{\substack{cal\\min}}] \qquad (11)$$

$$= a\ |S_{21}|$$

the 0 dB return-loss reference level and Γ_{in} can be established for future measurments. Once this calculation has been made then the following can be determined:

$$\frac{(V_A/V_R)^{1/2}_{\substack{cal\\max}} - (V_A/V_R)^{1/2}_{\substack{cal\\min}}}{2(V_A/V_R)^{1/2}_{\substack{cal\\avg}}} = |S_{22}| + \delta \qquad (12)$$

which will be useful in determining the measurement residual uncertainty. $|S_{22}|$ is the equivalent of the source mismatch, and is determined from (12) with uncertainty no greater than the A coupler directivity, δ.

If the DUT is connected to port 2 of the A coupler, a measurement of the reflected power from the input port of the DUT can be made. There is no control over the phase of the reflected power. It can be shown, therefore [Ref. 3:p. 185],

$$\frac{(V_A/V_R)^{1/2}_{DUT}}{(V_A/V_R)^{1/2}_{\substack{cal\\avg}}} = |\Gamma_{in}| + C_1\left|\frac{S_{41}}{S_{42}S_{21}}\right| + C_2|S_{22}||\Gamma_{in}|^2. \quad (13)$$

The constants C_1 and C_2 lie in the interval $[-1,1]$ and depend upon the phases of the directivity and equivalent source mismatch error signal components relative to the signal reflected from the input of the DUT. $|S_{22}|$ was found during the calibration and it is assumed that $|S_{21}|\approx 1$. $|S_{41}/S_{42}|$ is not generally known as a function of frequency but it is bound from above by the coupler directivity, D, as specified by the manufacturer. The detector voltage ratios may now be determined by

$$\frac{(V_A/V_R)^{1/2}_{DUT}}{(V_A/V_R)^{1/2}_{\substack{cal\\avg}}} = |\Gamma_{in}| \pm \Delta\Gamma_{in} \quad (14)$$

where the worst case uncertainty $\Delta\Gamma_{in}$ is given by

$$\Delta\Gamma_{in} = D + |S_{22}||\Gamma_{in}|^2 \tag{15}$$

In order for the proper 0 dB return-loss reference level to be determined for all phases of the input signal, the sliding short must be moved through a distance of at least one half of the guide wavelength, λ'. This will ensure that the signal passes through a full 360° of phase as illustrated in Figure 3b. The calibration algorithm can then determine the maximum and minimum values of (V_A/V_R) at each desired frequency as the sliding short is moved through a distance of $\lambda'/2$ at the lowest frequency in a specified number of steps, in this case 10. These values can also be used to compute the range of error for each measurement.

Interaction between the DUT, the source and the R coupler can be minimized through the use of a waveguide isolator between the R and A couplers. This will also minimize the equivalent source mismatch, $|S_{22}|$.

As a final note, the measured DUT input reflection coefficient is given by

$$\Gamma_{in} = S_{11}^{DUT} + \frac{S_{12}^{DUT}S_{21}^{DUT}\Gamma_L}{1 - S_{22}^{DUT}\Gamma_L} \tag{16}$$

where Γ_L is the reflection coefficient of the load terminating the DUT [Ref. 3:p. 185] Since $|\Gamma_{in}| = |S_{11}|$ for

the DUT only if $|\Gamma_L| = 0$, the best possible load should be placed on port B of the DUT when measuring $|\Gamma_{in}|$ at port A, and vice versa. To achieve the lowest uncertainty for return-loss and insertion-loss data, the unexcited port of the DUT should be terminated in a waveguide matched load. If a sliding load is used then the error due to load reflection may be averaged out in the same manner as the equivalent source mismatch error is averaged out during the return-loss calibration procedure. This will cause the process to be less automated, however, and some compromise may be necessary if a computer driven measurement system is desired.

2. Insertion Loss Measurement Analysis

Determining the insertion loss requires satisfying the equation

$$IL_{kq} = -10 \log_{10}(P_q^{-}/P_k^{+}) \qquad (17)$$

where P_q^{-} is the power scattered from port q of the DUT and P_k^{+} is the power incident on port k of the DUT. Looking at the basic setup in Figure 2b, this measurement is taken by terminating the network in the B-coupler and samples of the incident and scattered waves are coupled to ports R and B respectively. The square-law detectors at 3 and 6 produce the output voltages V_B and V_R. It can be shown that the ratio of these detector voltages in terms of the scattering coefficients of the DUT is given by

$$(V_B/V_R)^{1/2} = d\left[\frac{|S_{21}^{DUT}|}{|(1-S_{11}^{DUT}\Gamma_s')(1-S_{22}^{DUT}\Gamma_L')-S_{12}^{DUT}S_{21}^{DUT}\Gamma_s'\Gamma_L'|}\right] \quad (18)$$

where d is a constant, Γ_s' is the reflection coefficient seen looking into port 2 of the A coupler, and Γ_L' is the reflection coefficient seen looking into port 5 of the B coupler [Ref. 3:p. 185]. Calibration of the reflectometer for this measurement is done by placing the A and B couplers directly together. This results in the following relationships:

$$S_{11} = S_{22} = 0 \quad (19)$$

$$S_{12} = S_{21} = 1. \quad (20)$$

As a result

$$(V_B/V_R)^{1/2} = \frac{d}{|1 - \Gamma_s'\Gamma_L'|} \quad (21)$$

and the correct reference level (0 dB insertion loss) is located with an uncertainty equal to $\pm d|\Gamma_s'\Gamma_L'| << d$. The uncertainty can be reduced by making either Γ_s' or Γ_L' smaller which can be accomplished by removing the A-coupler during calibration and measurement for insertion loss. When this is done, $|\Gamma_s'|$ is determined solely by the isolator VSWR.

The location of the insertion loss reference level will have a worst case uncertainty determined by the system

component specifications. With the A-coupler in the system, the reflection coefficients Γ_s' and Γ_L' seen looking into the A and B couplers respectively are given by

$$\Gamma_s' = S_{22} + \frac{S_{24}S_{42}\Gamma_{D4}}{1 - S_{22}\Gamma_{D4}} \tag{22}$$

$$\Gamma_L' = S_{55} + \frac{S_{65}S_{56}\Gamma_{D6}}{1 - S_{66}\Gamma_{D6}}. \tag{23}$$

In each case the coupler port is effectively terminated (A-coupler by the isolator, B-coupler by the load). This makes each coupler appear as a 2-port network terminated in loads Γ_{D4} and Γ_{D6} respectively. As a result, the best possible results will occur when the detectors exhibit the lowest possible VSWR. Unfortunately millimeter-wave detectors generally have high VSWR's so an isolator with a lower VSWR preceding the detector may be necessary. Keep in mind that the secondary arm of the coupler will reduce the coupling factor by about 10 dB typically. The values of $|\Gamma_s'|$ and $|\Gamma_L'|$ for the reflectometer setup used in this paper are given in Chapter II, page 24.

The 0 dB reference uncertainty can be bounded more tightly by measuring the return loss of the B coupler during calibration. This will establish $|\Gamma_L|$. $|\Gamma_s|$ can be determined from the value of $|S_{22}|$, which was found during the return loss calibration (Equation 12) and Γ_{D4} from

manufacturer specifications. It can be shown that the calibration uncertainty is

$$20 \log_{10}(1+|\Gamma_s'\Gamma_L'|) \tag{24}$$

which is reduced since $|\Gamma_L'|$ is known from direct measurement at each frequency of interest [Ref. 3:p. 187].

With the DUT inserted between couplers A and B the insertion loss is determined by

$$\frac{(V_A/V_R)^{1/2}_{DUT}}{(V_B/V_R)^{1/2}_{DUT}}$$

$$= \left[\frac{|1-\Gamma_s'\Gamma_L'|}{|(1-S_{11}^{DUT}\Gamma_S')(1-S_{22}^{DUT}\Gamma_L')-S_{12}^{DUT}S_{21}^{DUT}\Gamma_S'\Gamma_L'|}\right]|S_{21}|. \tag{25}$$

Since there is no control over the DUT scattering coefficients, the measurement error depends upon Γ_s' and Γ_L'. Accurate measurements require the minimization of these two values.

In an automated system the value of the measurement along with the computed maximum and minimum measurement uncertainty can be easily graphed. This provides an easy graphical picture of the DUT response which can provide an immediate evaluation of the device performance.

II. SYSTEM DESCRIPTION

The Millimeter-Wave Scalar Network Analyzer system used for this thesis is illustrated in Figure 4. Specific Reflectometer components are listed in Table I. The full band sweeper and reflectometer are essentially the same as before but a new Schottky barrier detector diode was used in the A-coupler. The Reflectometer components yield a $|\Gamma_S| \leq 0.30$ and a $|\Gamma_L| \leq 0.12$ [Refs. 2,3]. The other major components are described below.

The new mainframes required software modification for proper computer interfacing. Conspicuous by its absence is the analog-to-digital converter which was eliminated by using the new mainframes. Although software modifications were required to communicate properly between mainframes, the computations used for determining the return loss and insertion loss remained essentially the same. Details on specific software modification are contained in the third section of this chapter.

A. Hardware

The five major components used for the Automated Millimeter-Wave Scalar Network Analyzer are as follows.

1. <u>Computer</u>: The HP-9845B microcomputer was used for this setup. Its 186K memory was sufficiently large for all storage and computational requirements. It was the

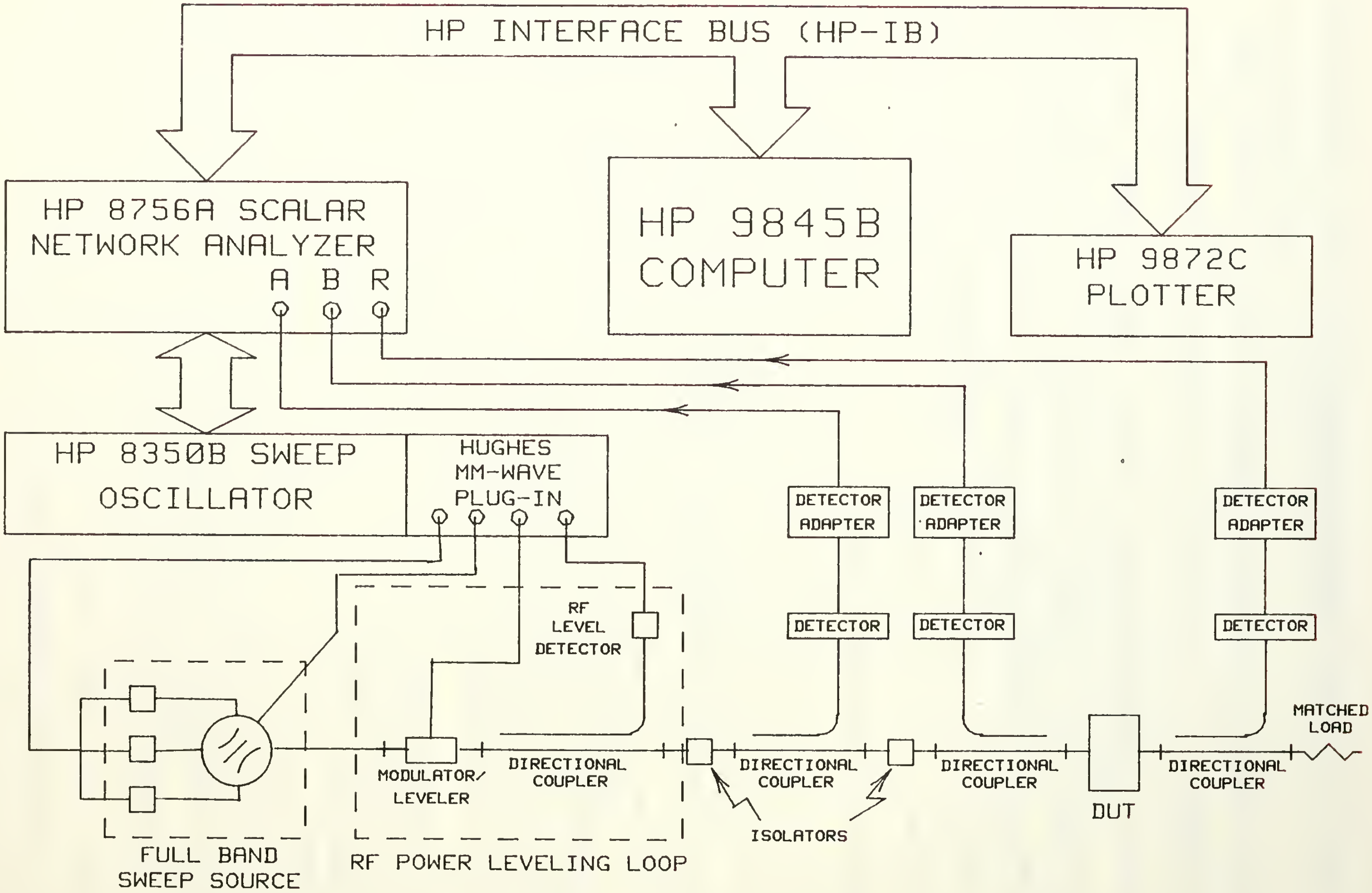


Figure 4. Diagram of an Automated Millimeter-Wave Scalar Network Analyzer System.

computer used for the original setup and software modifications were minimal and easily incorporated. The internal thermal printer was used for text output and could also be used for graphical output if desired.

2. Sweeper Controller: One of the new mainframes used for this setup, the HP-8350B, was interfaced with the HP-9845B computer through the HP-8756A Scalar Network Analyzer. The HP-8350B could be controlled either locally or remotely through the entire 60-90 GHz band by using the Hughes 47610H Millimeter-Wave Plug-In. One major advantage of the HP-8350B was the ability to switch the RF head on the Full Band Sweeper automatically through proper frequency selection. No separate band selection commands were required from the software. The primary disadvantage was that the entire millimeter band from 60-90 GHz could not be swept with a single command. In order to execute a full band sweep, the computer had to command a sweep from 60-70 GHz, then from 70-80 GHz, and finally from 80-90 GHz. This was necessary to activate the proper RF head in the Full Band Sweeper.

3. Millimeter Wave 60-90 GHz Full Band Plug-In: The Hughes 47610H Full Band Plug-in which was used in the original setup was used again for this setup. An adapter piece along with a ROM chip from Hughes Aircraft Company was required for proper interfacing with the HP-8350B Sweeper

Controller. The conversion was easily accomplished and no subsequent problems have occurred.

4. Scalar Network Analyzer: The HP-8756A Scalar Network Analyzer was the most important improvement to the system. Although the analyzer could be operated independently, its connection with the computer through the interface bus (HP-IB) allowed for complete computer control of all analyzer functions. The HP-8756A also had the ability to digitize the display sweep and transfer the values to the HP-9845B for storage and computations. The results using this analyzer were very good although there was one drawback. The display sweep is digitized to 401 points regardless of the START/STOP frequencies. This meant that great care had to be used for measurements taken nonsymmetrically around a band switch point. For example, to sweep from 65-72 GHz first requires the sweep from 65-70 GHz, then the sweep from 70-72 GHz since 70 GHz is the band switching point. The HP-8756A, therefore, will digitize the first sweep of 5 GHz (65-70 GHz) into 401 points and send that to the computer. It will then digitize the remaining 2 GHz (70-72 GHz) into 401 points and send that to the computer. As one can see, the result is that for the same frequency range in each band there are going to be a different number of samples taken resulting in accuracy differences. The easiest way to avoid this problem is to insure that the frequency width taken in each band is the

same, i.e., insure that the START/STOP frequencies are symmetrical about the band switch frequency.

5. Plotter: The HP-9872 series Plotter was a totally new addition to the system. In the previous system, the graphical output was only available from the HP-9845B internal thermal printer. This method was very quick, but all too often produced a copy which obscured the actual measured value and the bounds of uncertainty.

With only a few lines of code the user now has the capability of producing a larger, high resolution, multi-color output of the graphical data. By utilizing the fine tip pens and multi-color capability of HP-9872 plotter, even the tightest bounds to the actual reading came out dramatically clearer than with the thermal printer.

All of the graphical results in this paper were done on the HP-9872C Plotter. Although the plotter image takes longer to produce, this feature was a major improvement over the old system.

The Reflectometer components used for the measurements as well as the variable attenuator, sliding short and matched load used as DUTs are listed in Table I.

B. SYSTEM CONNECTION

Figure 4 shows the measurement system interconnections. The HP-IB connects the HP-8756A Scalar Network Analyzer mainframe and the HP-9872C Plotter with the HP-9845B

TABLE I

SPECIFIC REFLECTOMETER COMPONENTS USED FOR THE AUTOMATED MILLIMETER-WAVE SCALAR NETWORK ANALYZER

Component	QTY	Manufacturer	Part number
Full Band RF Source	1	Hughes	47125H-1100
Modulator/Leveler	1	Hughes	45215H-1100
Directional Coupler	4	Hughes	45325H-1010
Diode Detector	3	Hughes	47325H-1100
Diode Detector	1	Hughes	47325H-1111
Detector Adapter	3	H/P	11664C
Isolators	2	Hughes	45115H-1000
Variable Attenuator	1	Hughes	45725H-1000
Sliding Short	1	Baytron	3E-95
Matched Load	1	Hughes	45615H-1000

computer. The HP-8350B Sweeper Controller is connected via external bus to the HP-8756A. All computer commands for the sweeper pass through the analyzer.

The Hughes 47610H Millimeter-Wave Plug-in is internally connected to the Sweeper Controller with external connections to the Full Band RF Head for band selection and RF power control. Detector voltage outputs are fed through an adapter where the signal is amplified and impedance matched to the HP-8756A input. Power ratio measurements are displayed on the analyzer scope. The scope sweep is then digitized into 401 points and sent to the computer via the HP-IB. All computations for return and/or insertion loss are performed by the computer and the results outputted to

either the CRT, internal thermal printer or externally through the HP-IB to the HP-9872C plotter.

C. SOFTWARE

The old Millimeter-Wave Scalar Network Analyzer used a program entitled "AEK" which was developed by Lieutenant Elia Gatsos, Hellenic Navy [Ref. 4:pp. 78-94]. The analog nature of the HP-8755B Scalar Network Analyzer precluded sweeping the band of interest continuously since the analyzer output could not provide a digitized sweep output to the HP-9845B computer. The band had to be divided into individual frequencies spaced across the desired band in steps which were selected by the user; 100 MHz for example. With the HP-8620C Sweeper Controller in the CW mode (vice FREQUENCY SWEEP mode), the computer would send the individual frequencies to the Sweeper Controller. At each step the output from the HP-8755B would be routed through the A/D converter to the computer where it would be stored in an array.

In the new system, the HP-8756A Scalar Network Analyzer has the capability of digitizing a sweep and outputting the measured values directly to the HP-9845B computer as a serial string of values which can be read directly into an array. The sweep is always digitized into 401 points. The program had to be modified to provide for this increased

capability. The commands were much simpler and arrays could be initiated with a maximum number of 401 points.

The HP-8350B Sweeper Controller required a few extra commands to ensure only one band was swept at a time. The only way to position the RF head on the Reflectometer to the proper position was to have the START/STOP frequencies fall within a particular band. This meant that to sweep across the entire band from 60-90 GHz required three series of commands from the computer; 60-70 GHz, 70-80 GHz and 80-90 GHz.

To provide consistency in the measurements, 401 points were always used. For a sweep in one band this was no problem. When sweeps across two or three bands were required, some data manipulation was required to ensure equally spaced data points between the start and stop frequencies. Additional computer commands were required, therefore, for processing the HP-8756A data.

Handling 401 data points provided excellent results but required lengthy computations for calibration and measurement (due to a number of looping operations). To allow for faster computation times at the expense of resolution, a selection of 7 choices for total number of data points used was provided for the user. The lowest number, 10, was used for trouble shooting the program. Computations were very fast but the results were not of much use for actual measurements. The remaining numbers, up to

401, give increasing degrees of resolution and longer computation times. The user must determine the number of points versus computation time required for a particular measurement.

The final major program modification involves adding a feature which was not previously available. The internal thermal printer will produce a graphic representation of the measurement (return loss or insertion loss). At times the measurement and the boundaries for the range of error become so close that it is difficult to distinguish between them. It would be helpful to have a larger, clearer graphic image.

With this in mind, the capability of plotting the graphic image on the HP-9872 plotter was incorporated into the program. The image can be as large as the plotting surface (11" x 17") and can have up to 4 colors for greater clarity. This feature proved very successful and greatly enhanced the output capabilities of the system.

Other minor program modifications were added to provide for more user friendliness. During the sliding short calibration all data is taken before the 0 dB return loss reference level is computed. This reduces the user interfaced time required to move the position of the sliding short.

The measurement sequence for insertion loss in the old program was the same with or without the A-coupler in the system. With the A-coupler in the system, the sequence was

rearranged to provide fewer user interfaces resulting in a faster measurement process.

The number and magnitude of program modifications justified renaming the program from "AEK" to "MMWSNA". A flow chart of the program is shown in Figure 5.

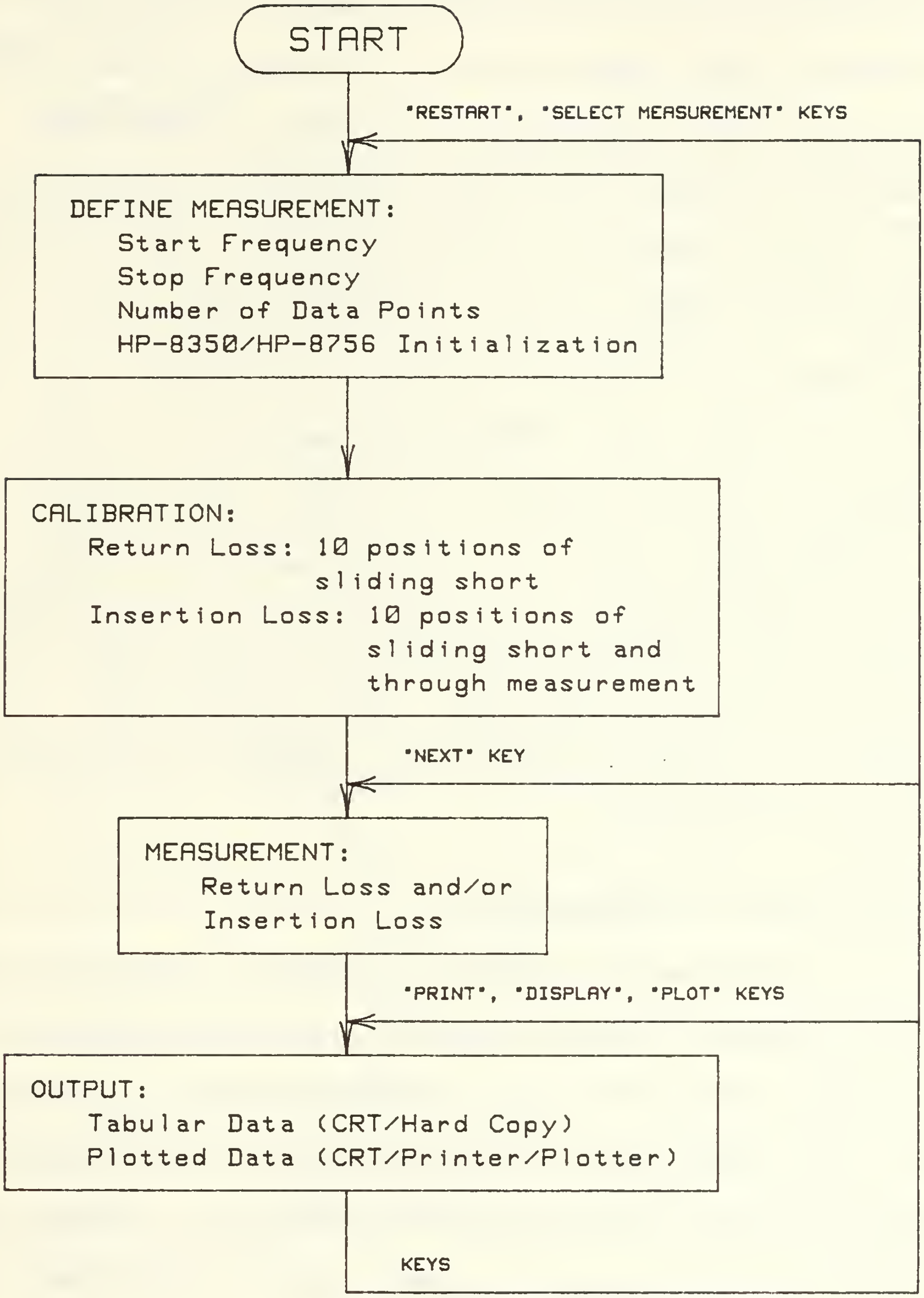


Figure 5. Measurement Flow Chart for "MMWSNA" Program.

III. <u>RESULTS</u>

The number of tests which were used to verify the performance of the improved Millimeter-Wave Scalar Network Analyzer precludes reviewing all of them in this paper. A representative sample have been chosen to illustrate the return loss and insertion loss capabilities and many more were used to determine certain system parameters such as dynamic range. This chapter reviews the measurements and provides illustrations to characterize them. Accuracy measurements with the improved analyzer also include tabular data. Some comparisons will also be made so that the improved system data can be compared with data gathered in previous theses, known systems, and manufacturers' components. The MMWSNA User Guide (Appendix A) may be helpful as a reference.

A. RETURN LOSS MEASUREMENTS

As mentioned in the Chapter 1, Section C, the analyzer must be calibrated prior to performing measurements for return loss. The system was calibrated using a sliding short. The short was moved to ten different positions ensuring that the short was positioned over a length greater than 2.5 millimeters which is equal to $\lambda/2$ at 60 GHz. Sufficient accuracy is attained using 100 to 200 data points for the measurements thus reducing the calculation times. Aside from user inputs to the program and moving the sliding

short, the computer performs all the setup, data gathering, and calculations for establishing the 0 dB return loss reference point.

1. Calibration

To ensure that the system was properly calibrated, measurements of a short and a matched load were performed. Expected return loss values of 0 dB and some maximum value in excess of 30 dB were expected for the short and load respectively. The first measurements were performed with the existing whisker diode detectors and yielded the return losses shown in Figures 6 and 7. In the measurement plots, the middle curve is the actual device measurement and the upper and lower curves bound the measurement uncertainty. The fixed short return loss looked good but the matched load return loss was a disappointing 20 dB. Subsequent system checks and measurements made with a calibrated attenuator verified that the system was working properly but the maximum measurable return loss was about 20 dB.

Defective detector diodes were believed to be the cause of the poor system performance. A newer Schottky barrier diode detector was purchased from Hughes Aircraft Company (Serial no. 030). The performance of this detector was much improved. Figures 8 and 9 show the return loss for the short and matched load return losses respectively.

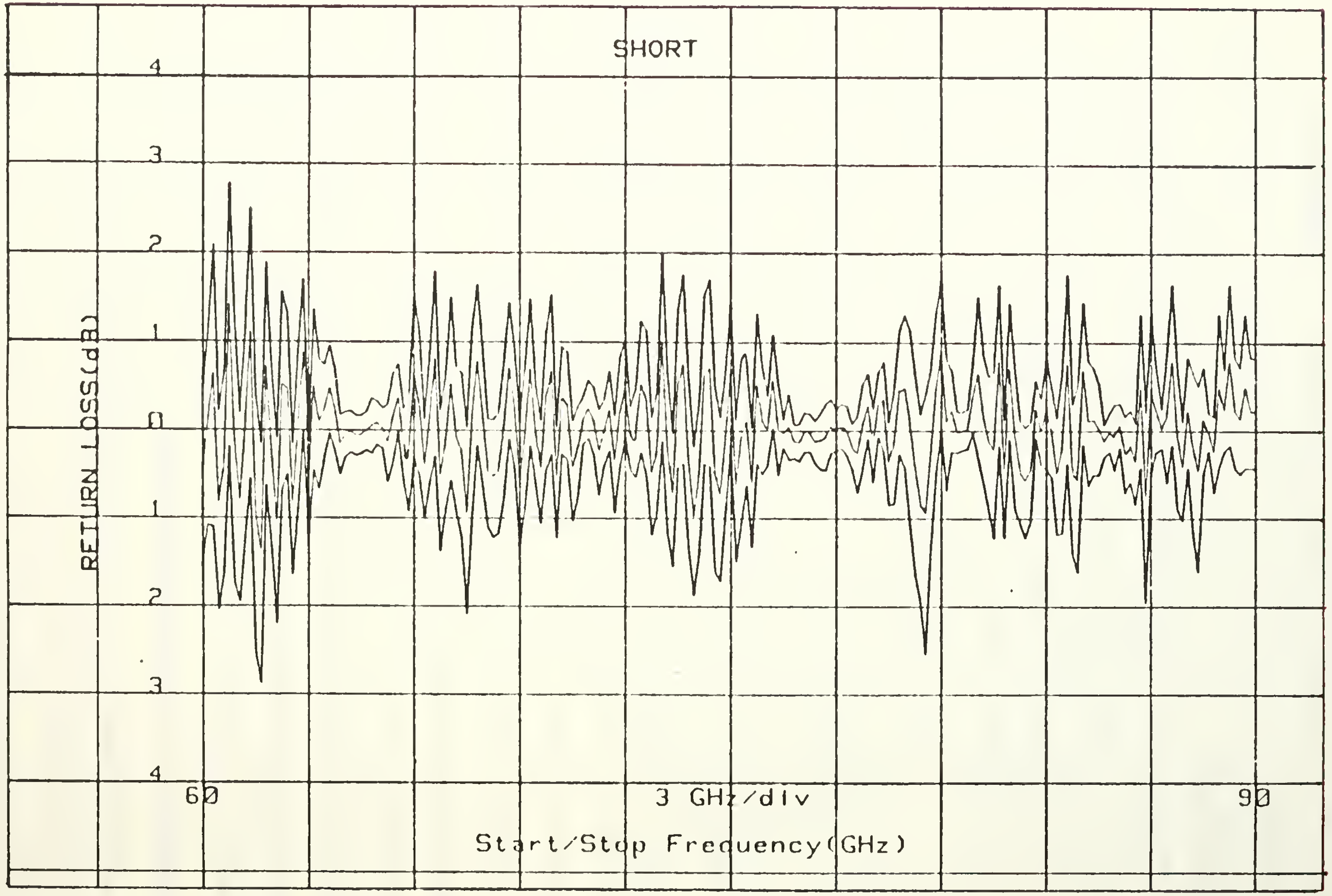


Figure 6. Fixed Short Return Loss Using Whisker Diode Detector.

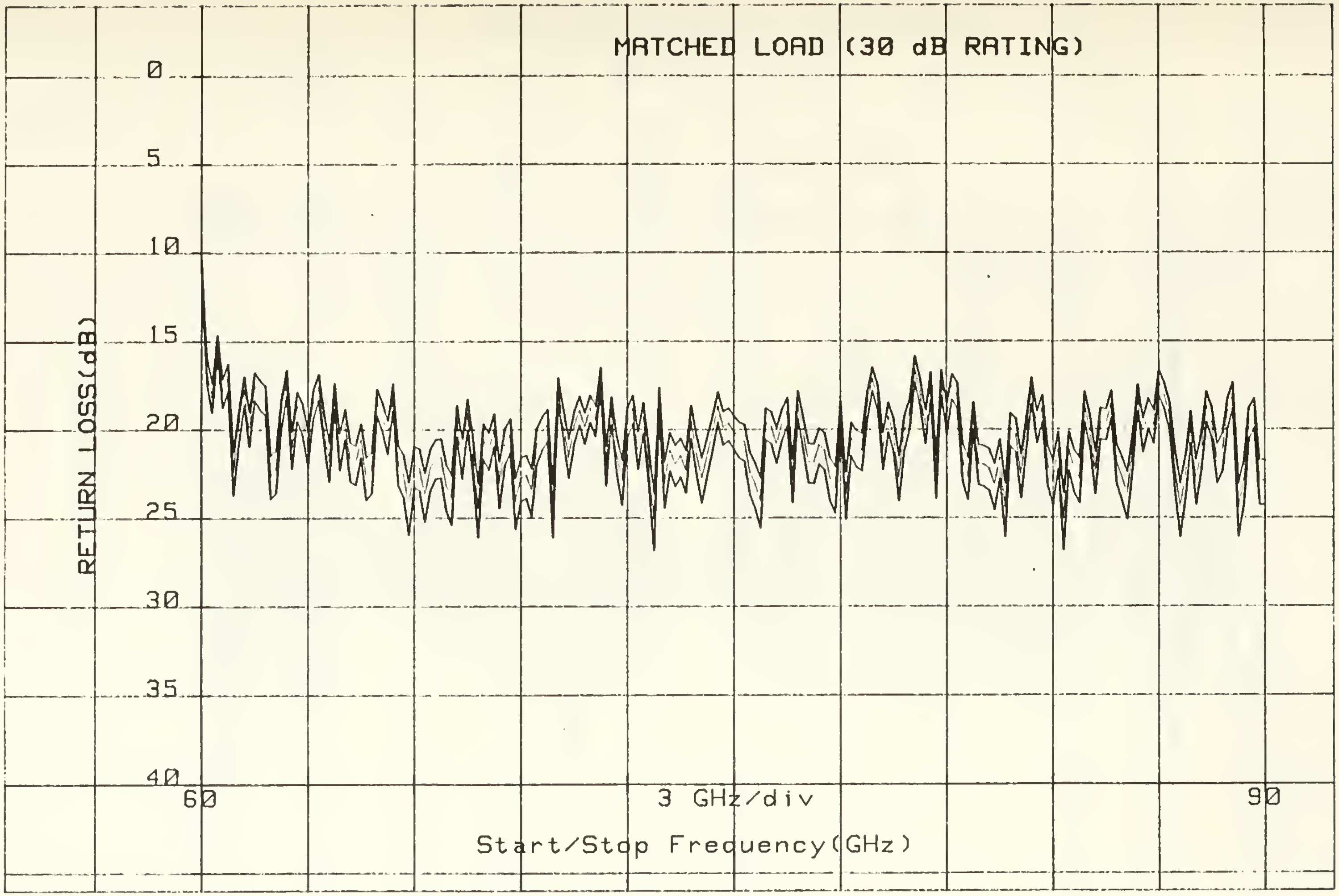


Figure 7. Matched Load Return Loss Using Whisker Diode Detector.

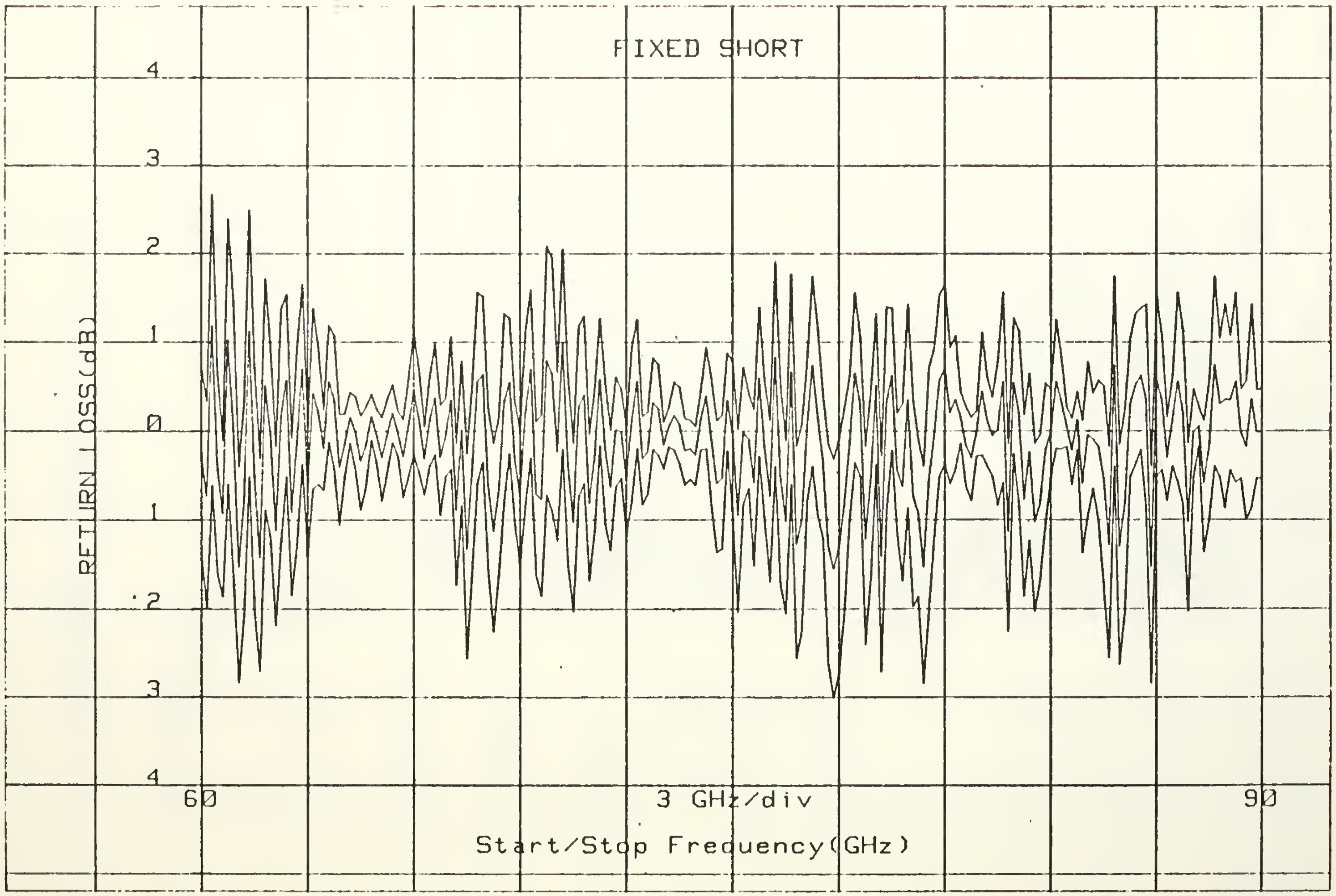


Figure 8. Fixed Short Return Loss Using Schottky Diode Detector.

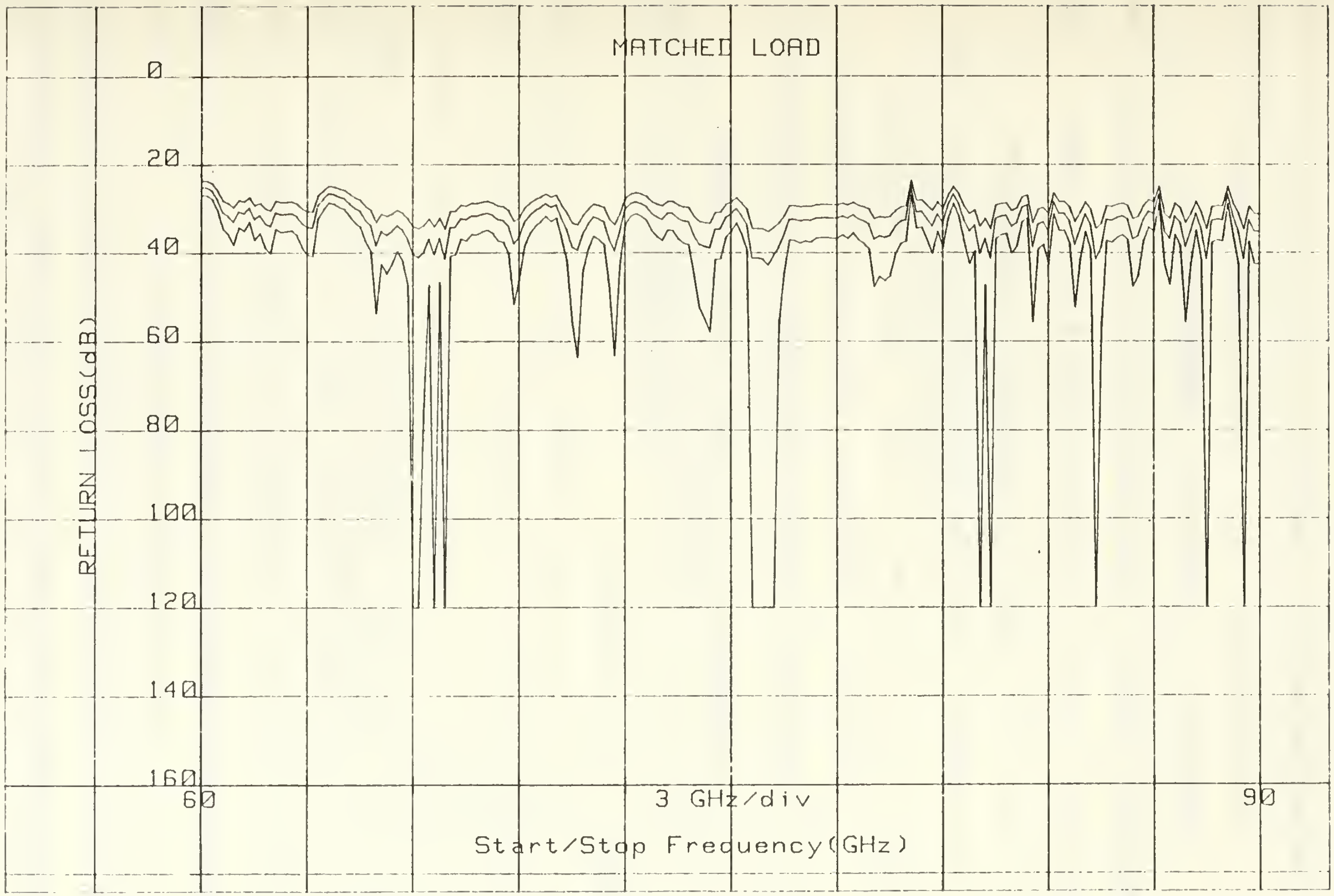


Figure 9. Matched Load Return Loss Using Schottky Diode Detector.

The printed tabular data can be found in Appendix C, Tables II and III. The Schottky barrier diode detector appeared to have a much better dynamic range.

a. Minimum Uncertainty Computation Problem

Graphical results from the Matched Load return loss (Figure 9) showed discontinuities at various points associated with the Minimum Uncertainty plot. A more detailed study shows that the disconinuity occurs when the return loss exceeds 40 dB. Analysis of the equations used to determine return loss uncertainty reveals the problem.

In Chapter I Section A, the return loss worst case uncertainty, $\Delta\Gamma_{in}$, was given by Equation (15). This calculation is performed at line 4170 of the "MMWSNA" program. The variable cross reference between Equation (15) and "MMWSNA" is as follows:

$\Delta\Gamma_{in}$ = R3(X)

S_{22} = R6(X)

Γ_{in} = R19(X)

D = 0.01 (Manufacturer specification [Ref. 2:p. 104])

Equation (15) and line 4170 compute the worst case uncertainty, $\Delta\Gamma_{in}$ and R3(X) respectively, by using the worst case value of D, that being the Manufacturer's specification. When a high return loss occurs, the computed value of the worst case uncertainty, R3(X), can exceed the value of the input reflection coefficient, R19(X). In this

case the computation for the minimum uncertainty, R5(X), results in the logarithm argument being negative and, therefore, meaningless resulting in a discontinuity ("MMWSNA" line 4240).

As an example, in Table III the values of the variables for the matched load return loss at 66.00 GHz are as follows:

$$\Gamma_{in} = -40.25 \text{ dB or } 9.71628 \times 10^{-3}$$

$$S_{22} = -23.57 \text{ dB or } 66.298 \times 10^{-3}$$

$$D = 0.01$$

Using these values the worst case uncertainty is:

$$\Delta\Gamma_{in} = (9.71628 \times 10^{-3})^2(66.298 \times 10^{-3}) + 0.01$$

$$= 10.00626 \times 10^{-3}$$

The minimum uncertainty (R5(X)) = 20 $\log_{10}(\Gamma_{in}-\Delta\Gamma_{in})$ = 20 $\log_{10}(-289.98 \times 10^{-6})$ which is, of course, meaningless. To bypass this problem a default value of 120 dB was given to R5(X) for these cases ("MMWSNA" lines 4240 and 4250). The interpretation of this result is that there is a minimum value of uncertainty but it cannot be evaluated using the worst case coupler directivity. The value of the directivity for the coupler at that frequency would have to be known. For return losses of this magnitude, however, the parameter of greatest interest is normally the maximum

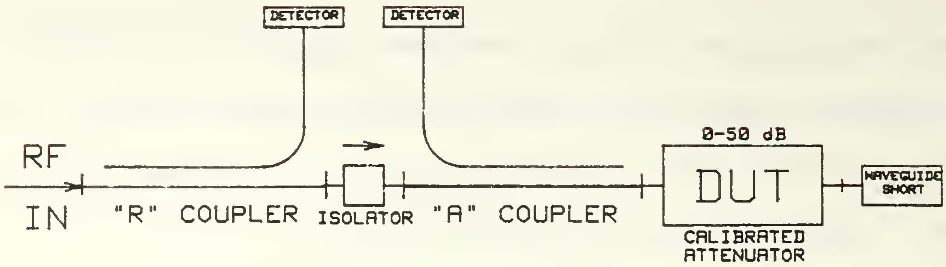


Figure 10. Calibrated Return Loss Setup.

return loss uncertainty and not knowing the minimum uncertainty is usually inconsequential.

2. Return Loss Accuracy

To gather data concerning the accuracy of the system for return losses throughout the dynamic range, a DUT consisting of a calibrated attenuator with a short at the output was used. The attenuator was a Hughes 4572xH series Millimeter-Wave Direct Reading Attenuator which has a specified accuracy of 0.1 dB or 0.2 percent, whichever is greater [Ref 2:pp. 34-35]. The setup is illustrated in Figure 10. The RF signal is attenuated twice; once as it passes through the attenuator to the short and again by an equal amount (the attenuator is a reciprocal device) as it returns from the short through the attenuator and into the A-coupler where it is detected. The return loss should be twice the attenuator setting. The return loss using the whisker diode for attenuator settings of 5 dB, 10 dB, and

12.5 dB are illustrated in Figures 11, 12, and 13 respectively.

The Schottky detector return losses for attenuator settings of 5 dB, 10 dB, 15 dB and 18 dB are shown in Figures 14, 15, 16 and 17. Printed outputs can be found in Appendix C, Tables IV, V, VI and VII. From this data the Schottky detector appears to have a much better dynamic range although in both cases the Return Loss did not stay within the specified accuracy of the attenuator.

3. Dynamic Range

To show the improved performance of the Schottky diode, values of return loss for 65 GHz, 75 GHz and 85 GHz were obtained and plotted to determine and compare dynamic ranges. The results are shown in Figure 18. It is not difficult to see from these graphs the superior performance of the Schottky barrier diode detector. Moreover the dynamic range for the Schottky diode is about 35-40 dB which is easily as good as that of commercially available systems.

a. Diode Detector Comparison

The reason for the superior performance of the Schottky diode detector is not immediately evident. An analysis of the output voltage was conducted and some clues as to the reason were revealed.

In a series of separate measurements, an oscilliscope was connected to two different whisker diode detector outputs and the Schottky barrier diode detector

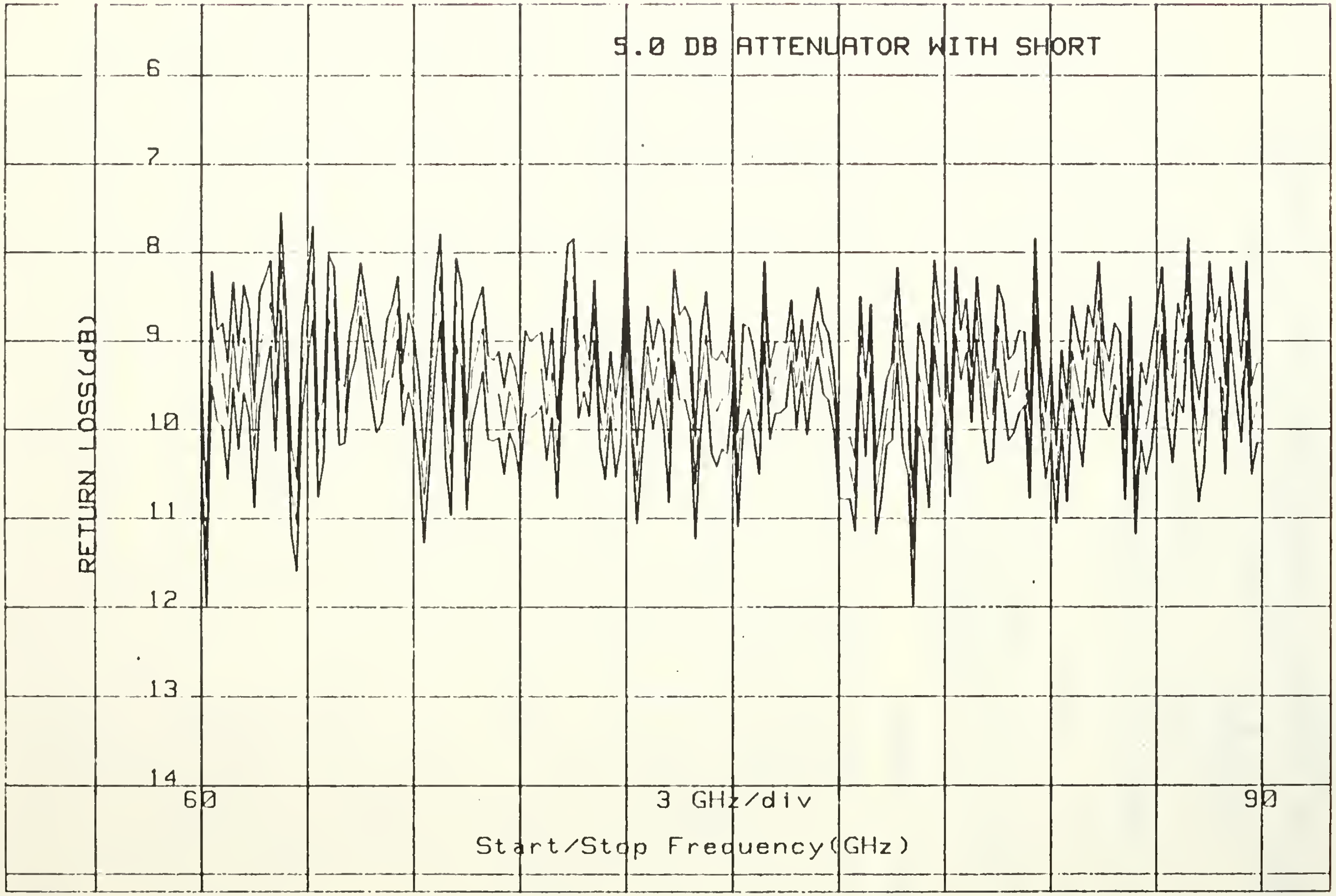


Figure 11. Return Loss for 5 dB Attenuator With Shorted Output Using Whisker Diode Detector.

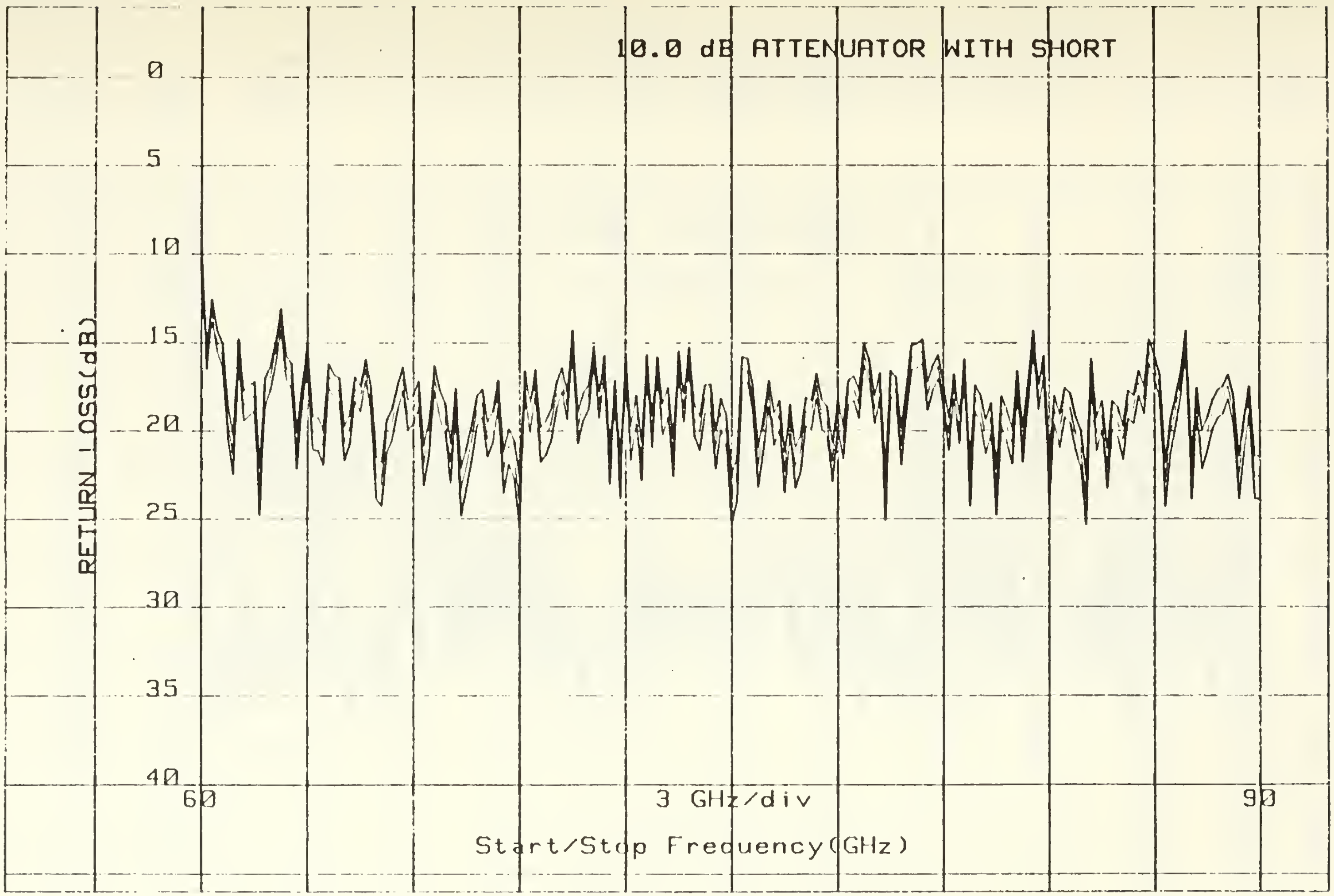


Figure 12. Return Loss for 10 dB Attenuator With Shorted Output Using Whisker Diode Detector.

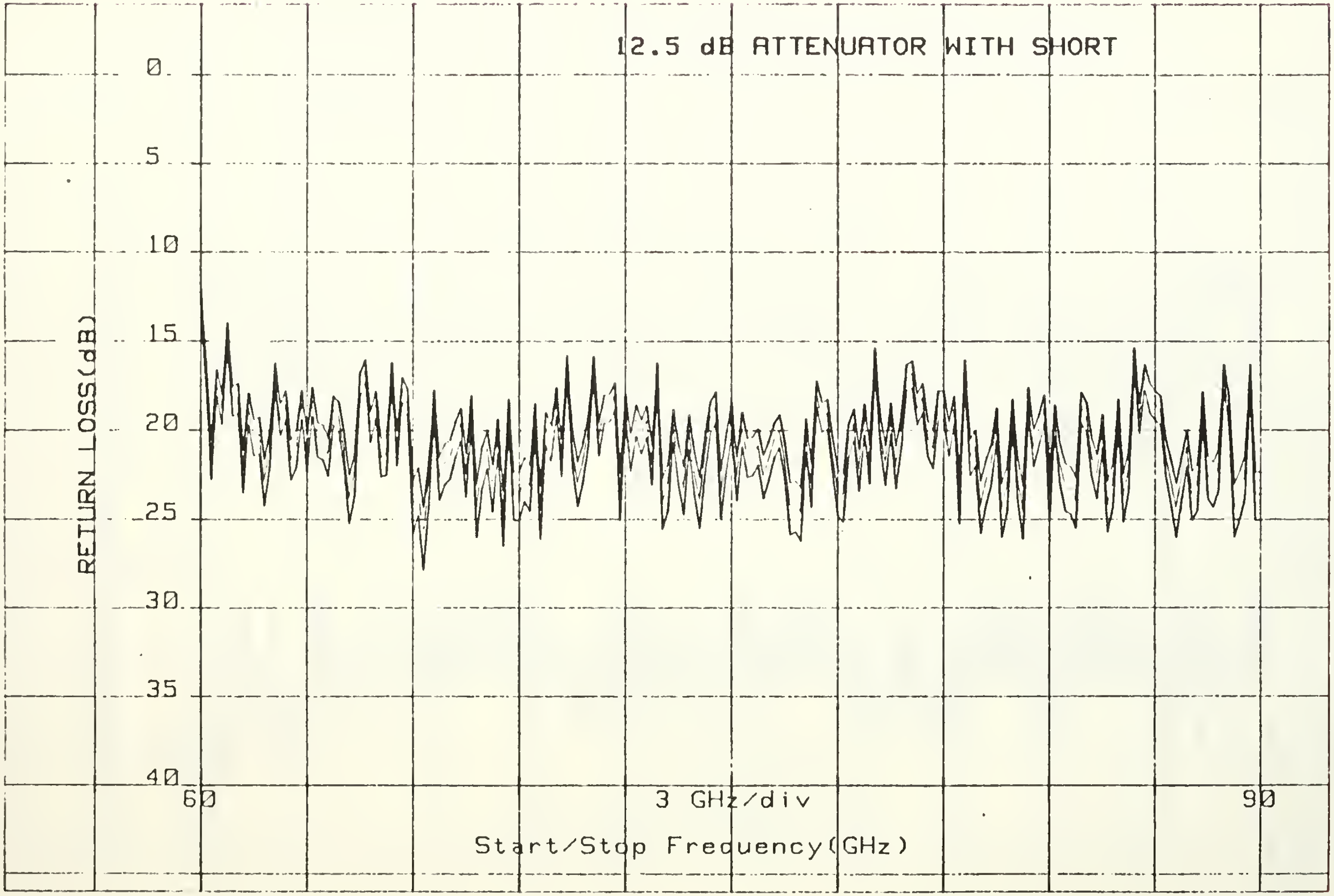


Figure 13. Return Loss for 12.5 dB Attenuator With Shorted Output Using Whisker Diode Detector.

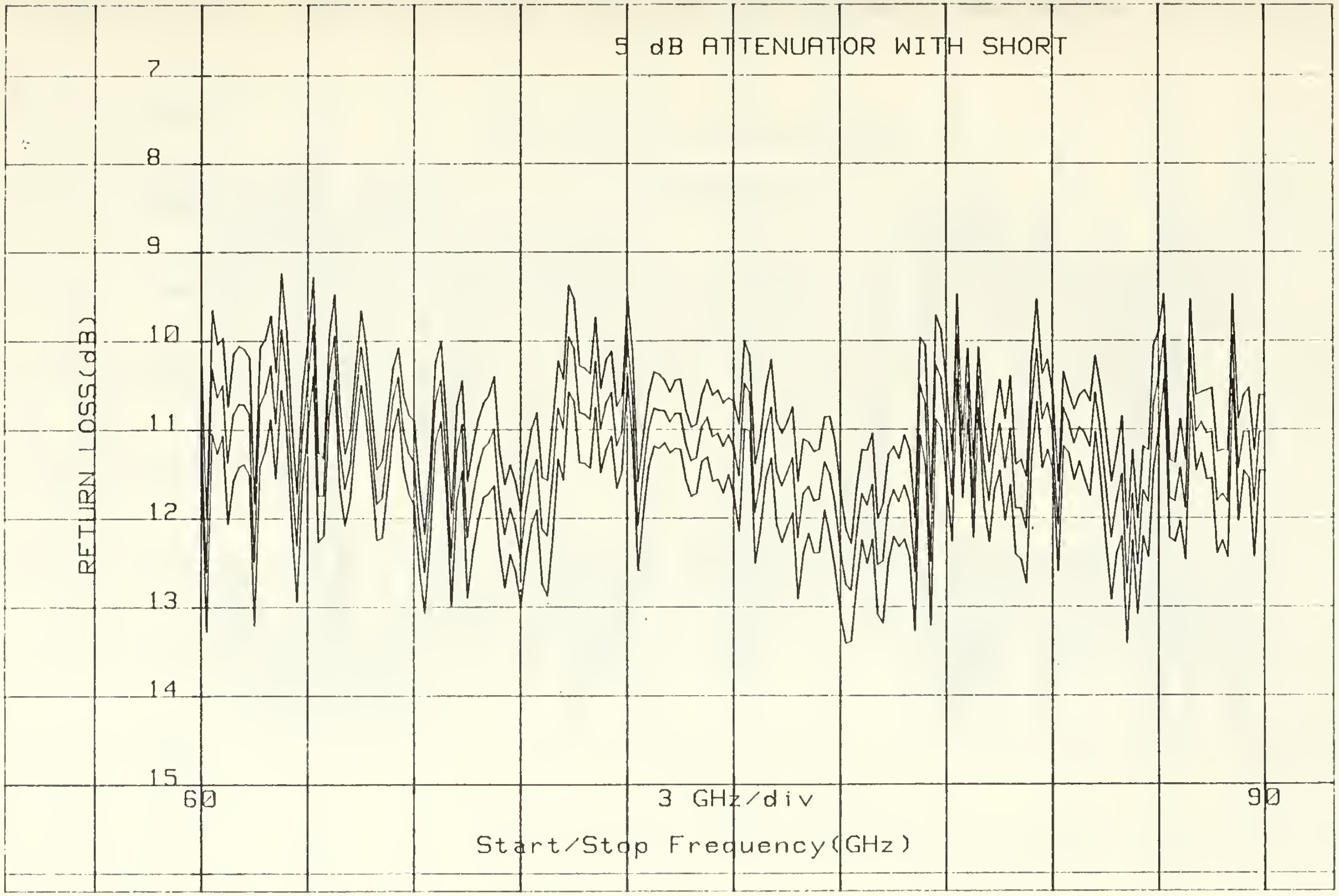


Figure 14. Return Loss for 5 dB Attenuator With Shorted Output Using Schottky Diode Detector.

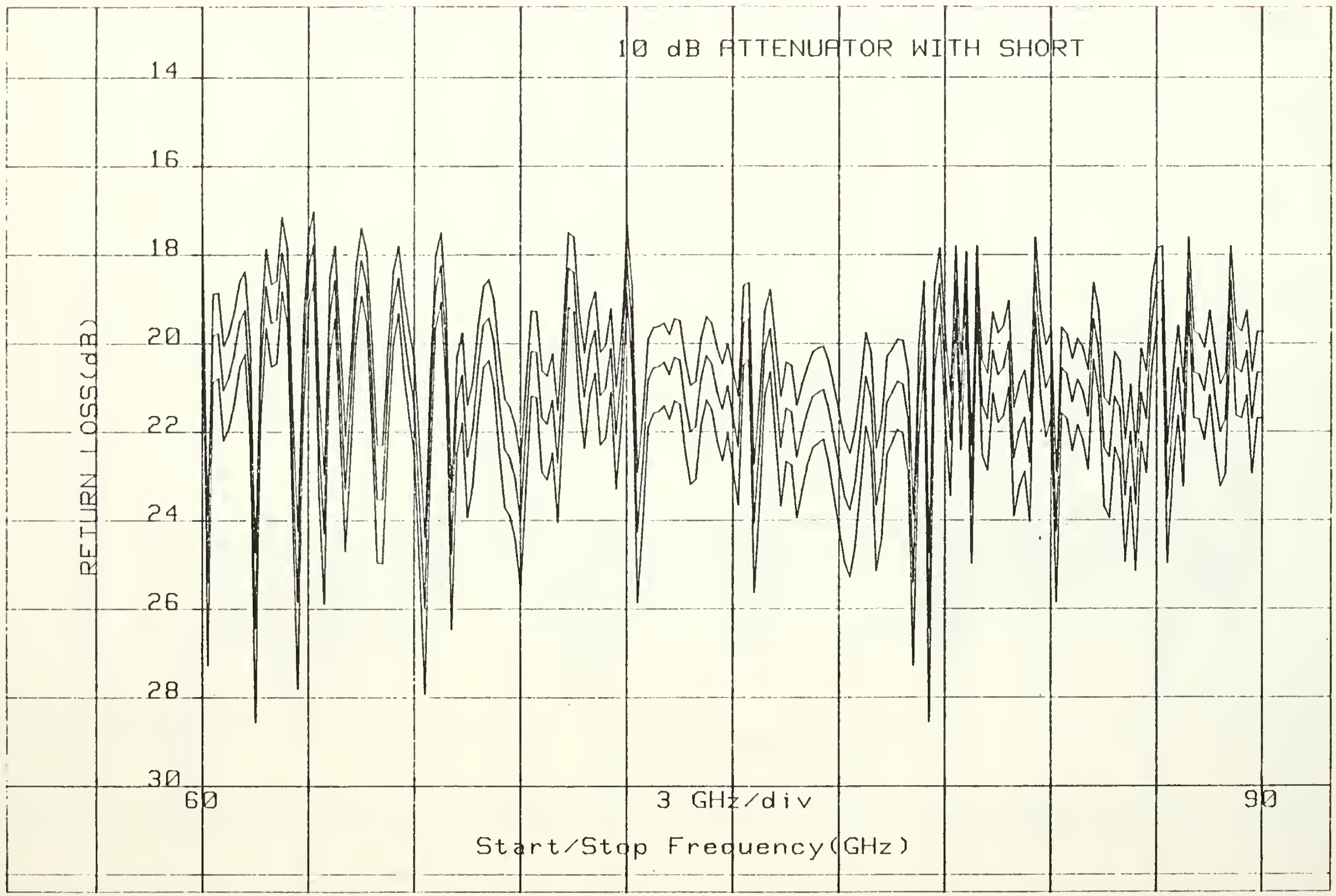


Figure 15. Return Loss for 10 dB Attenuator With Shorted Output Using Schottky Diode Detector.

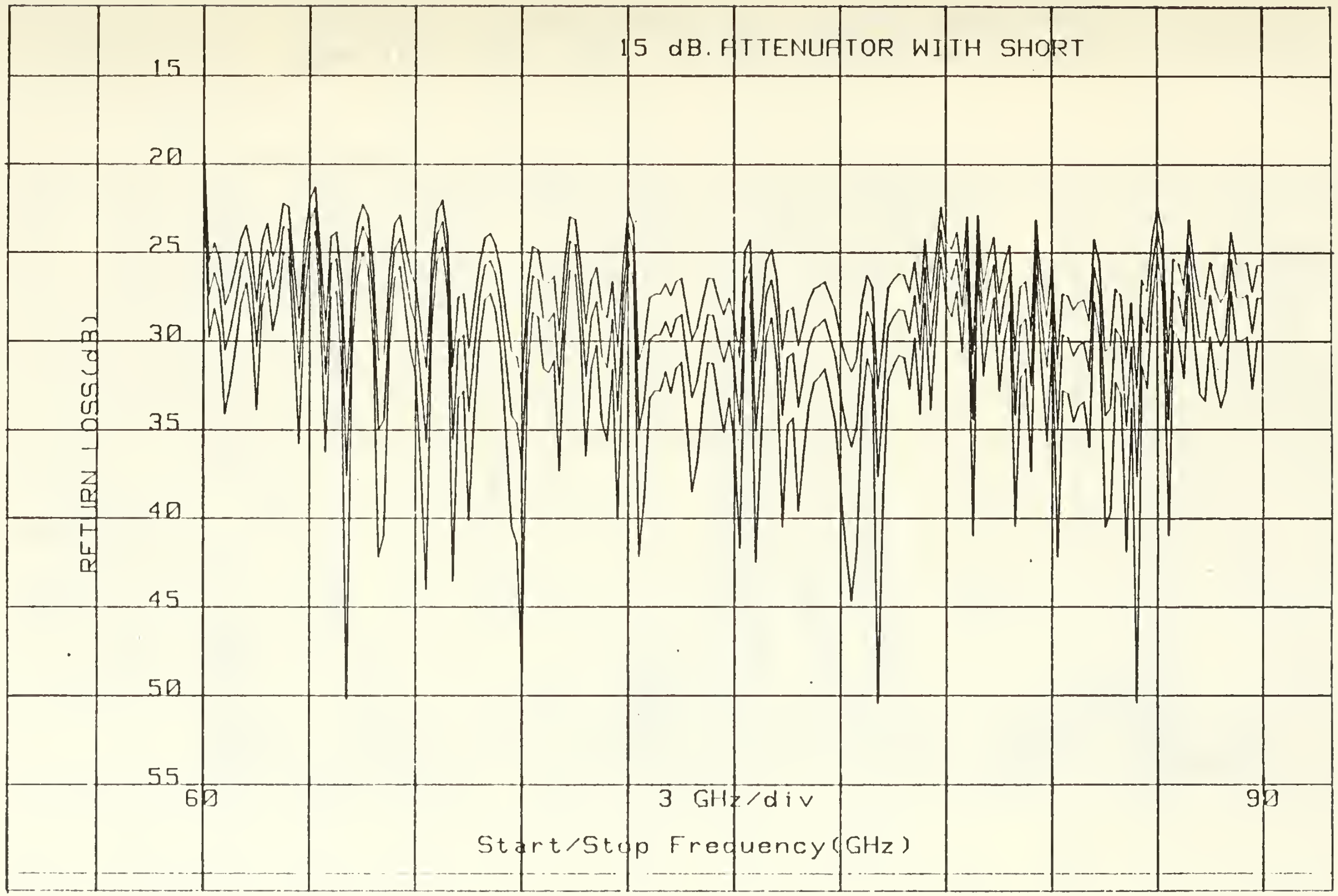


Figure 16. Return Loss for 15 dB Attenuator With Shorted Output Using Schottky Diode Detector.

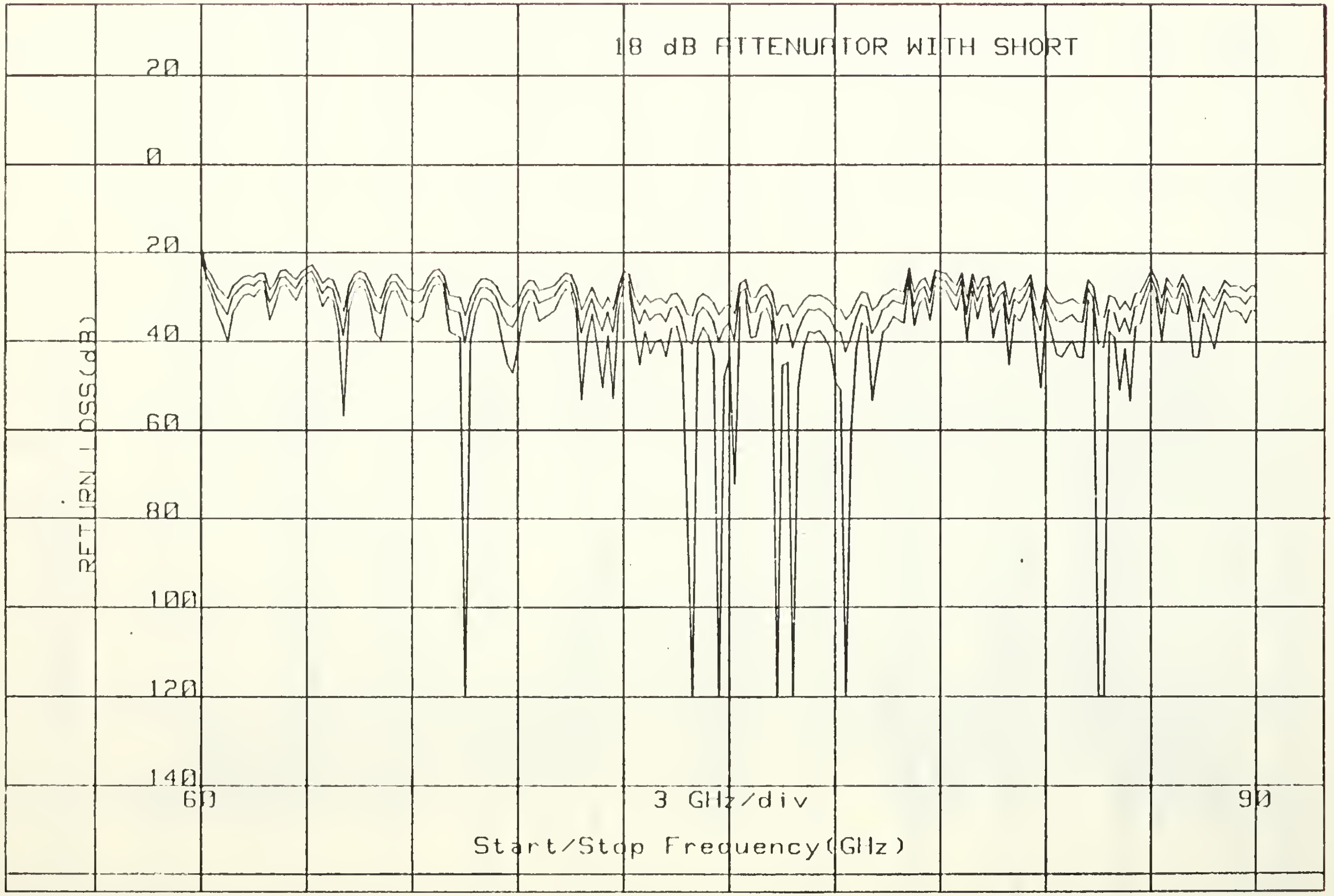


Figure 17. Return Loss for 18 dB Attenuator With Shorted Output Using Schottky Diode Detector.

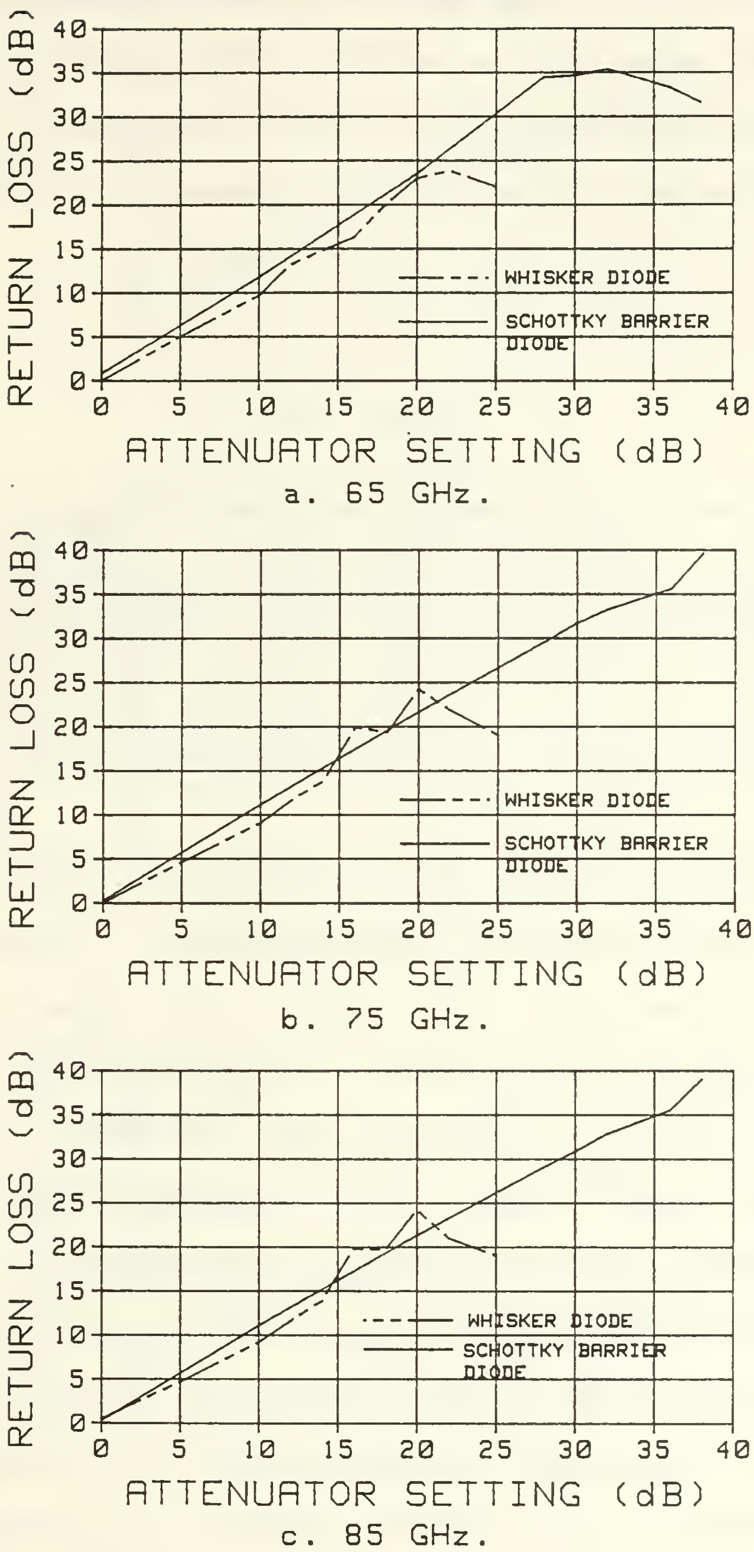


Figure 18. Dynamic Range for Return Loss.

output. Readings on the waveform peak-to-peak voltage and the DC level were taken at 60 GHz, 75 GHz and 90 GHz. The results are contained in Table VIII. Additionally, graphs of the RMS output voltage vs. input power are illustrated in Figure 19.

TABLE VIII

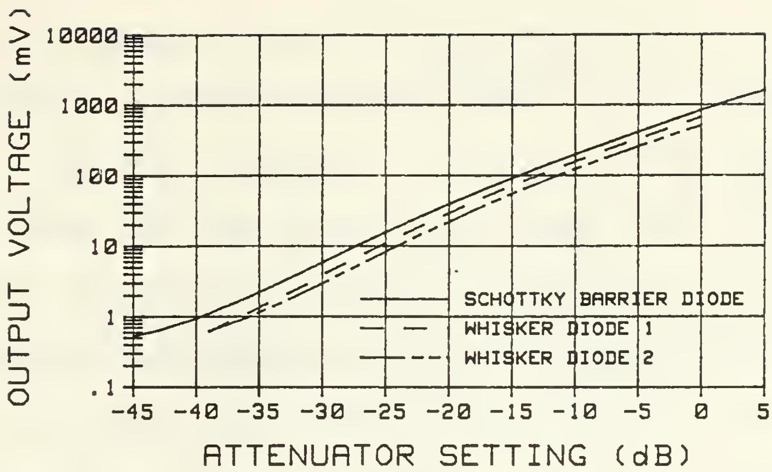
DIODE DETECTOR VOLTAGE LEVELS

Diode Detector	Peak-to-Peak Voltage			DC Level		
	60 GHz	75 GHz	90 GHz	60 GHz	75 GHz	90 GHz
Whisker No. 1	2.0mV	2.5mV	1.5mV	3.0mV	2.8mV	2.0mV
Whisker No. 2	2.0mV	3.0mV	2.5mV	-2.0mV	-1.0mV	-0.5mV
Schottky	1.2mV	1.8mV	2.0mV	55.0mV	42.0mV	32.0mV

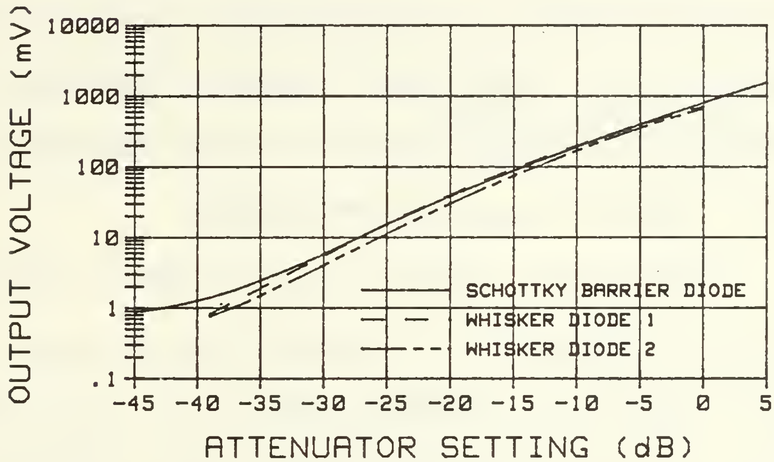
The peak-to-peak voltage of the waveforms did not vary a great deal but the DC level was substantially higher for the Schottky barrier diode. As a result, the output voltages for the Schottky diode detector in Figure 19 were consistantly higher across the band. This may be one reason the Schottky detector had a greater dynamic range.

4. <u>Comparisons With Previous Theses Results</u>

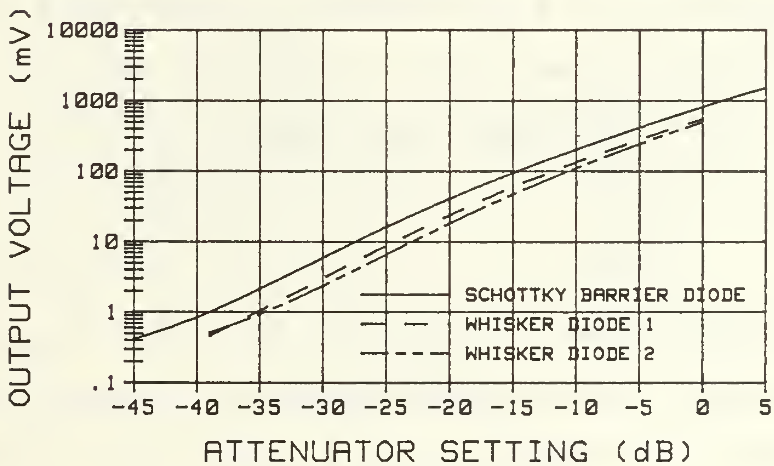
This improved system could only be considered as viable if devices which were measured in previous theses as well as devices offered by manufacturers were measured by the new system and the results compared. In previous Naval Postgraduate School theses a number of devices were tested



a. 65 GHz.



b. 75 GHz.



c. 85 GHz.

Figure 19. Diode Detector Output Voltage Comparison.

for return loss to determine the performance of the old system [Refs. 1,4]. The same devices were tested with the new system and the graphical results compared.

a. Fixed Short From 60-70 GHz and 70-80 GHz

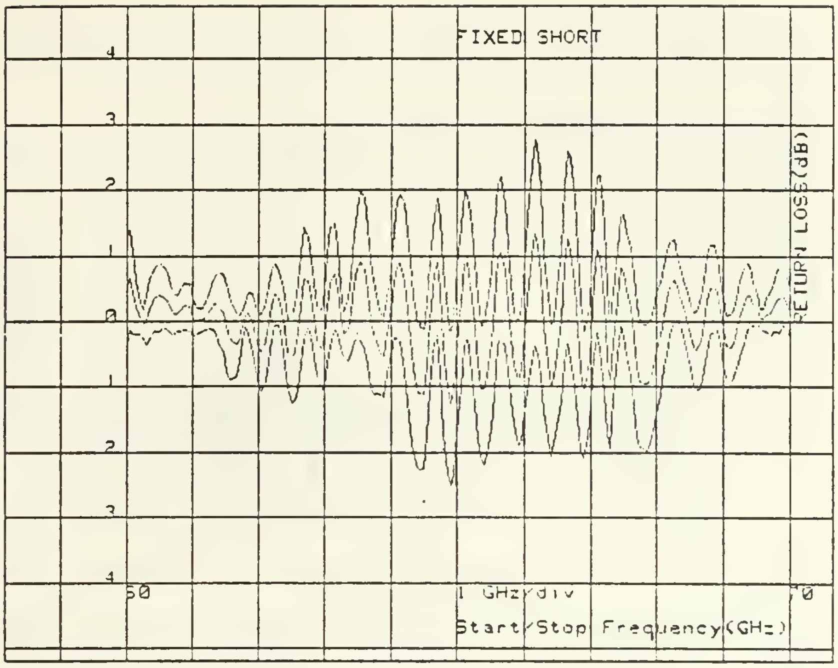
In Figures 20 and 21 a comparison of fixed short return losses from 60-70 GHz and 70-80 GHz respectively are shown. Aside from a pattern difference caused by a phase difference between the two measurements, the average value and variation of both the measurement (center line) and the uncertainties (outer line) are virtually the same. Both systems appear to perform equally for this device.

b. Tunable Load from 70-80 GHz

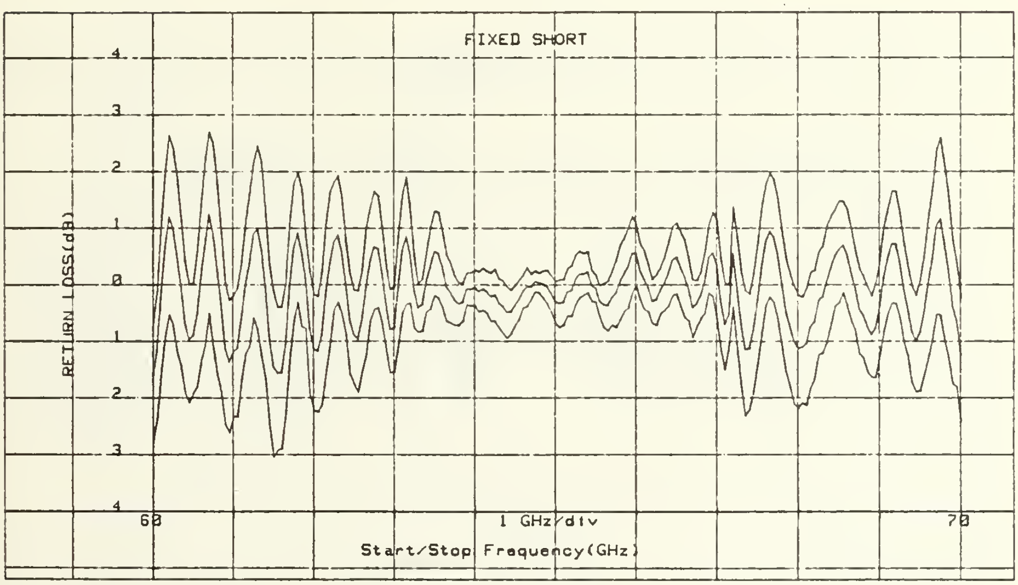
The return losses for a tunable load at mid-band are compared in Figure 22. Although the original thesis did not specify the setting of the load [Ref. 1:pp. 37-38], the tunable load for the improved system was a Hughes 45665 Tunable Load set at 2.00 (maximum setting was 5.00). Hughes specification for the tunable load VSWR is 1.05:1 nominal or 32 dB of return loss [Ref. 2:p. 112].

c. Detector Mount from 70-80 GHz

A comparison of the return loss for a detector mount from 70-80 GHz is contained in Figure 23. The previous test (Figure 23a) indicates an increase of return loss at about 75.5 GHz while the recent test (Figure 23b) indicates a relatively flat response from 70-80 GHz. One would hope that a detector mount would offer a uniform

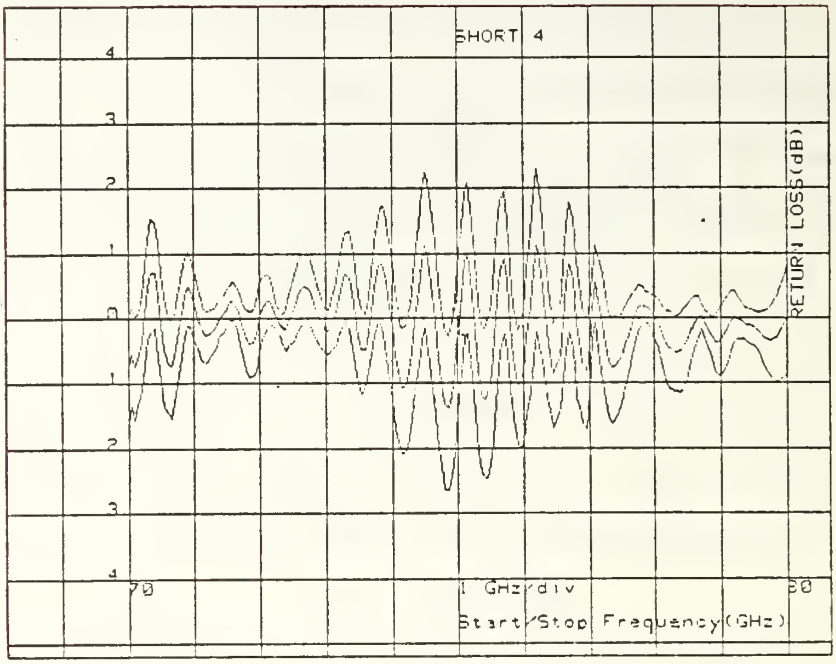


a. Old System.

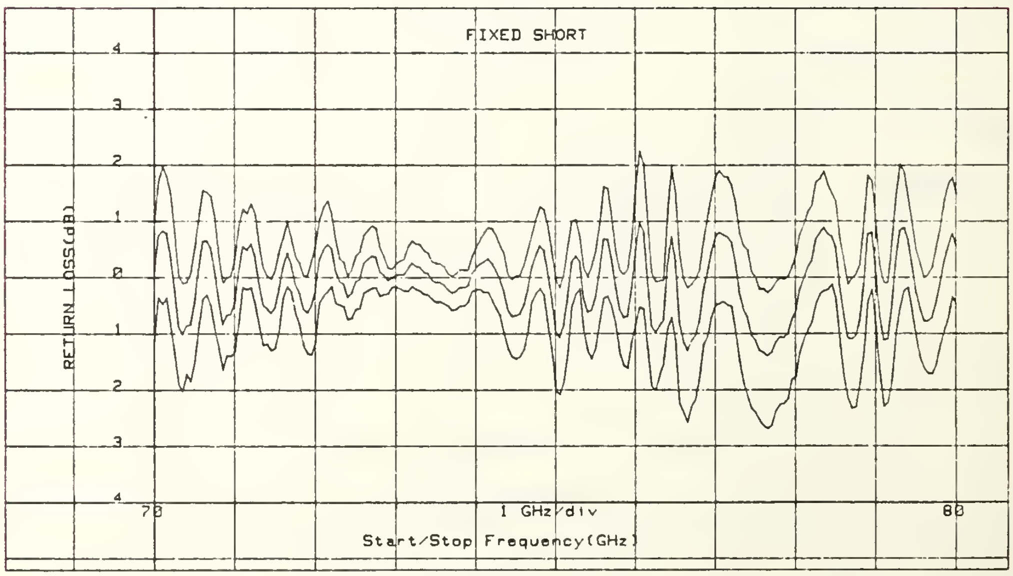


b. Improved System.

Figure 20. Fixed Short Return Loss Comparison from 60-70 GHz.

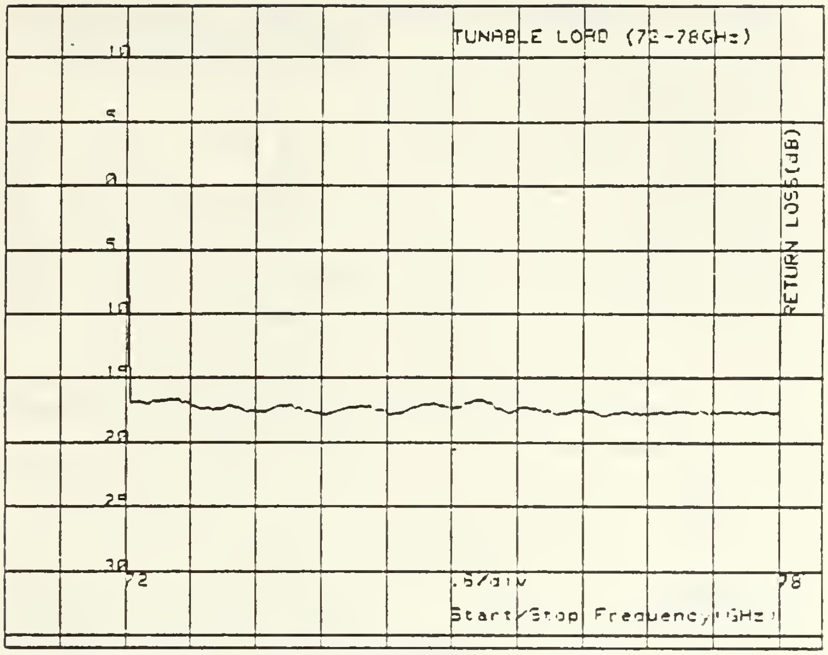


a. Old System.

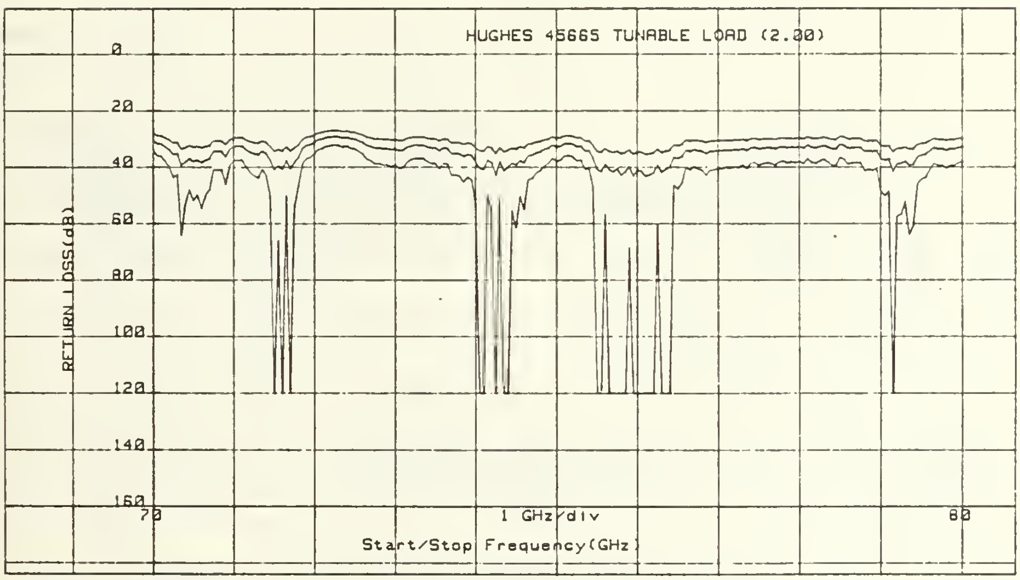


b. Improved System.

Figure 21. Fixed Short Return Loss Comparison from 70-80 GHz.

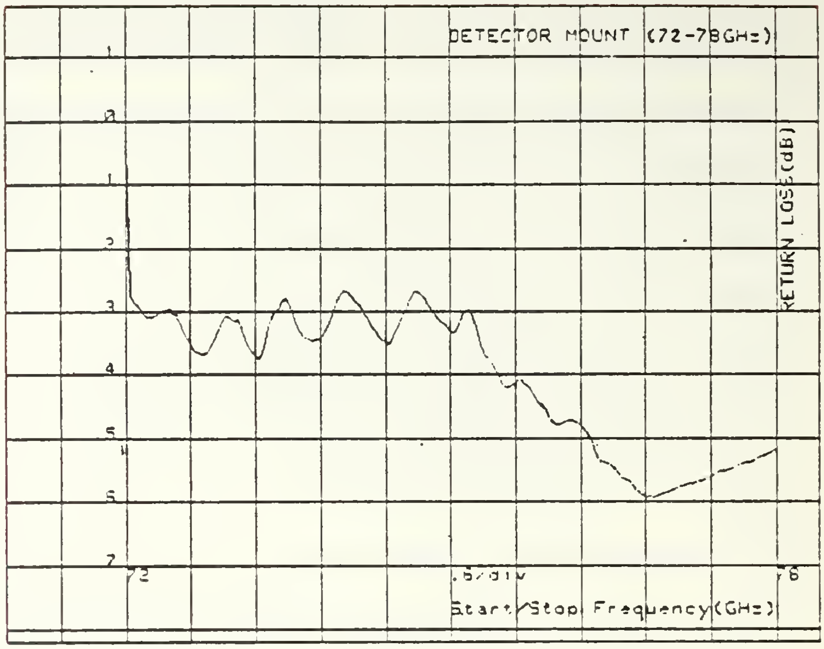


a. Old System.

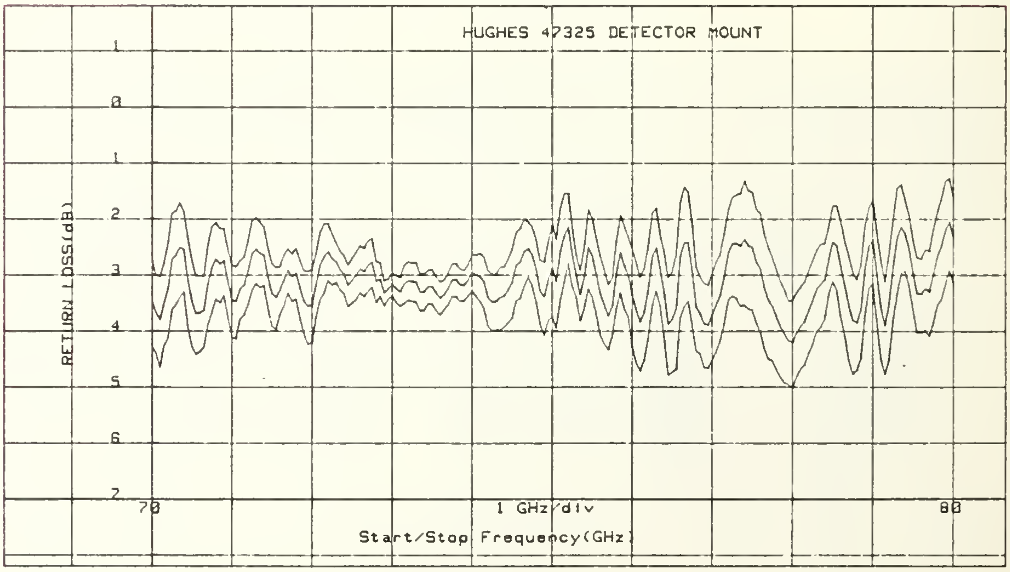


b. Improved System.

Figure 22. Tunable Load Return Loss Comparison from 70-80 GHz.



a. Old System.



b. Improved System.

Figure 23. Detector Mount Return Loss Comparison from 70-80 GHz.

response to an input especially at mid-band. This detector, the Hughes 4732xH series, did not have a specified VSWR but flatness was specified as ±1.5 dB max [Ref. 2:p. 90]. The comparison in Figure 23 is not conclusive but the improved system is showing a response which seems to be more reasonable for this type of device.

5. Comparison With Manufactured Device

The final comparison of return loss was made using a Baytron Horn Antenna (Part No. 7E-67/25). The rated return loss for this antenna is advertised at 1.2 VSWR or 20.7 dB [Ref. 5:p. 14]. Figure 24 shows the return loss for the antenna at mid-band, 70-80 GHz. The return loss is well above the 20.7 dB rating which indicates that both the antenna and the Millimeter-Wave Scalar Network Analyzer work as advertised.

B. INSERTION LOSS MEASUREMENTS

The insertion loss measurements made with the Millimeter-Wave Scalar Network Analyzer followed much the same pattern as the return loss measurements. This section first discusses the calibration of the system for insertion loss. The results using the calibrated variable attenuator to determine the accuracy and range of the insertion losses are then discussed with graphical and tabular results given. A comparison of performance between the whisker and Schottky diodes is also given. The section finishes up with a

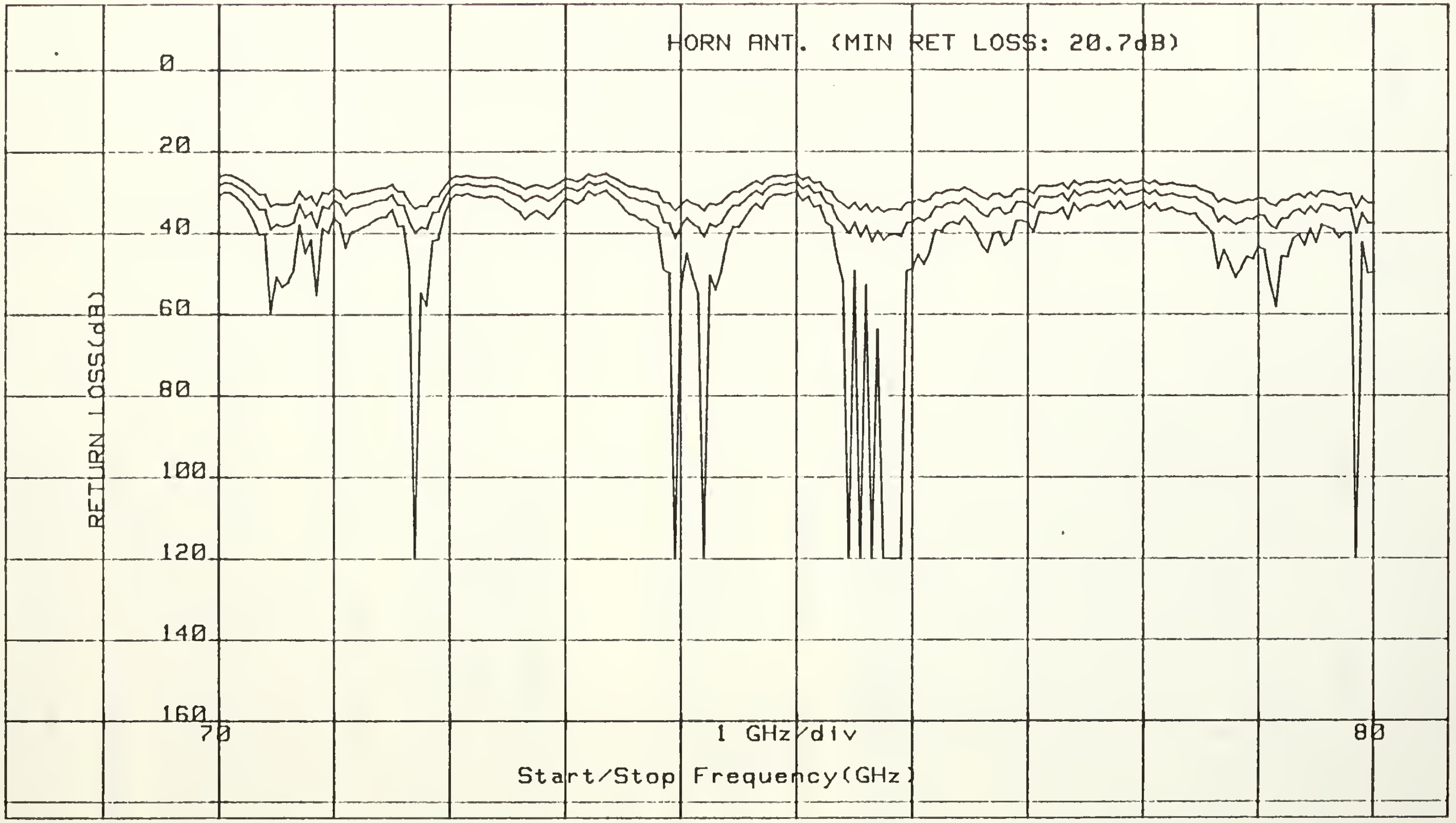


Figure 24. Return Loss for Horn Antenna from 70-80 GHz.

comparison of several devices which were tested in previous theses. Only graphical results are given for these comparisons.

1. Calibration

As discussed in the Background Information, the system must be calibrated with no DUT to determine a baseline for measurements. First, the return loss calibration is performed to determine $|S_{22}|$. Next, the system must be calibrated with the B-coupler installed. Referring to Figure 4, if the A-coupler is used, then the A and B couplers are placed together to form a through section of zero length. If the A-coupler is removed, then the B-coupler is placed directly on the isolator at the output of the R-coupler for this measurement. Once this is performed, DUT measurement can begin.

2. Insertion Loss Accuracy

The whisker diode detectors were used first to allow the A-coupler to remain installed for the measurement as illustrated in Figure 2b. Insertion losses for 0 dB, 10 dB, 20 dB and 25 dB settings on a variable attenuator are shown in Figures 25, 26, 27 and 28 respectively. Once again the maximum measured insertion loss was only about 20 dB.

As with the return loss, the whisker diode detectors were thought to be the problem with the range. Only one Schottky diode was available and replacement of either the A detector or the B detector did not improve the performance

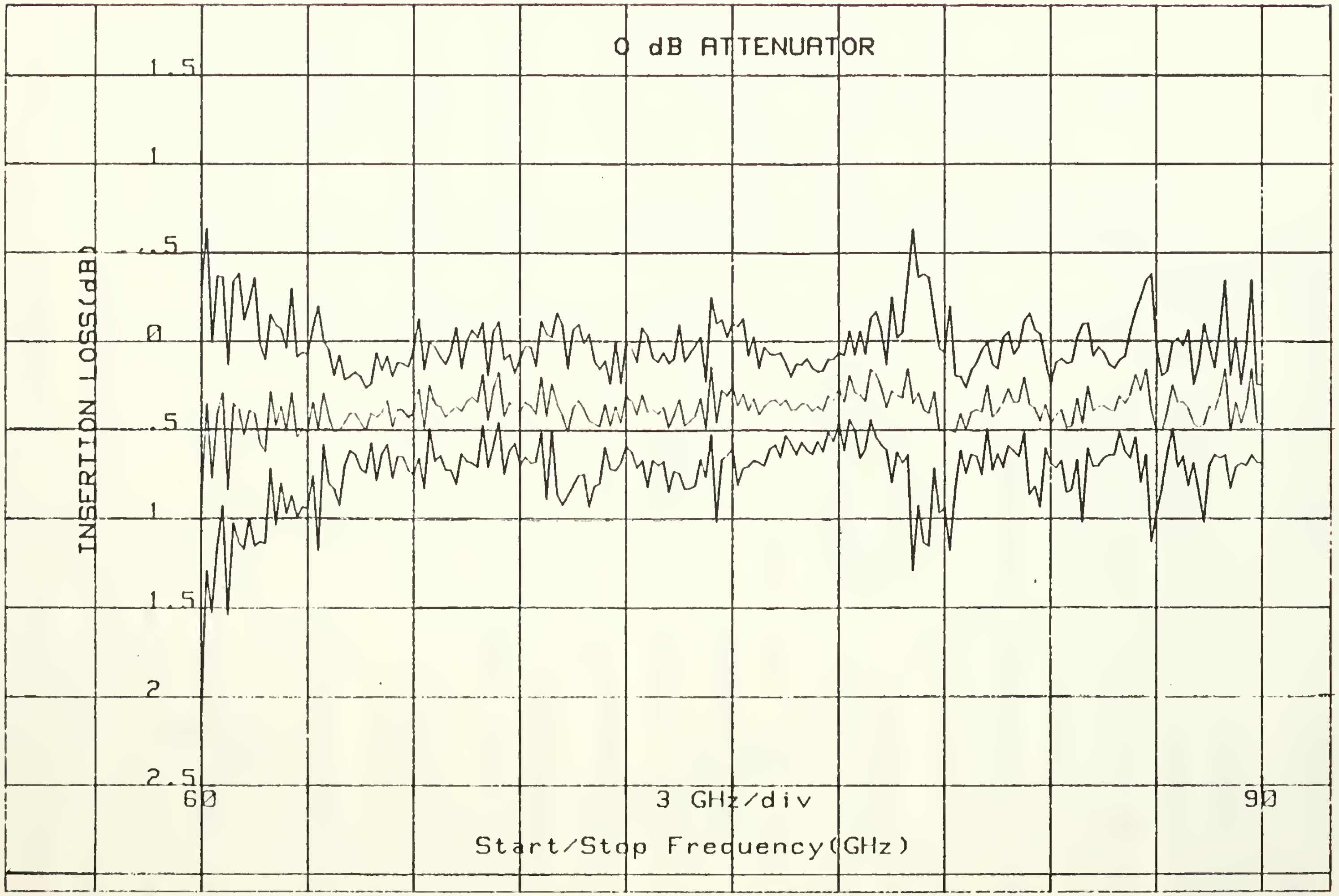


Figure 25. Insertion Loss for 0 dB Attenuator Using Whisker Diode Detector.

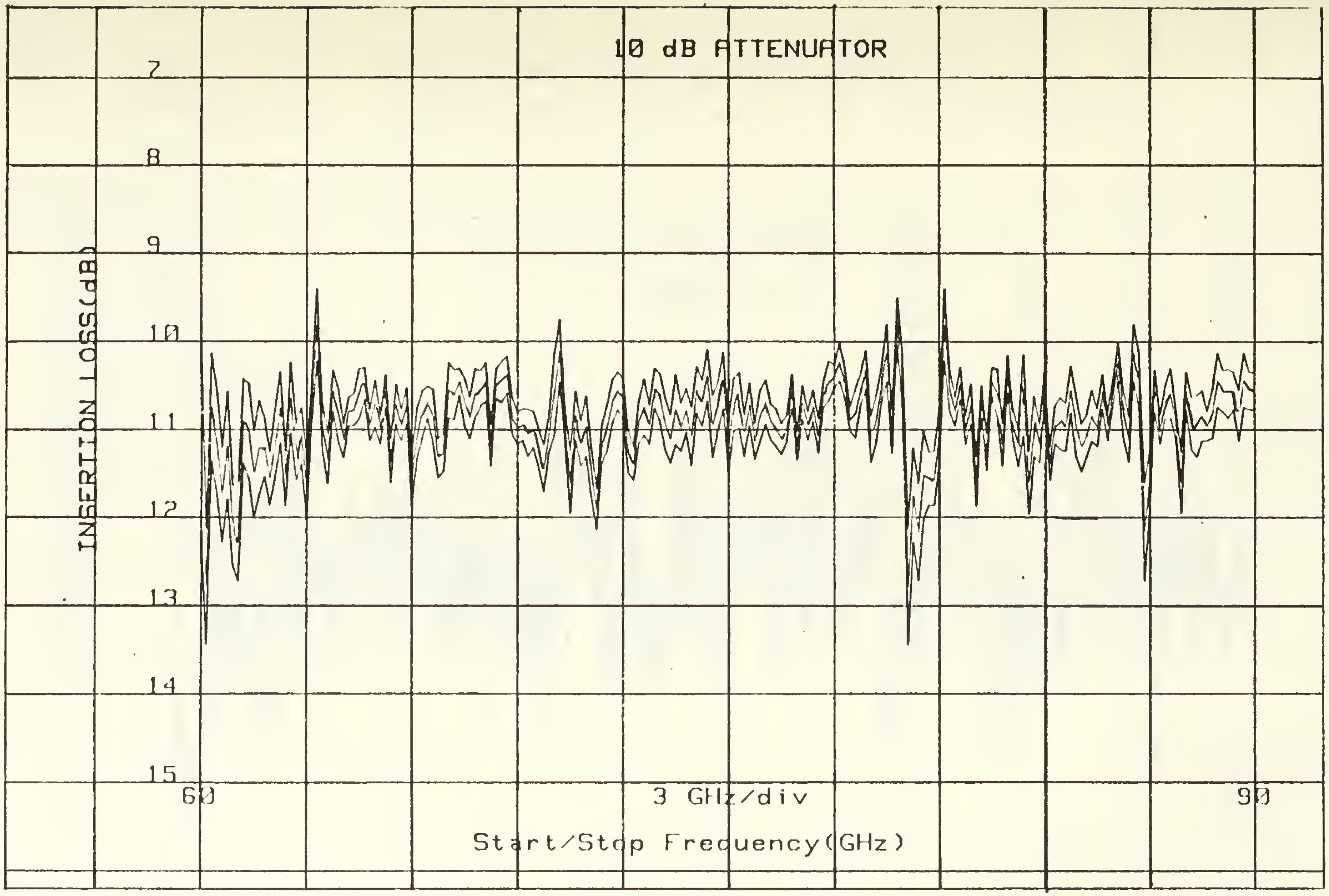


Figure 26. Insertion Loss for 10 dB Attenuator Using Whisker Diode Detector.

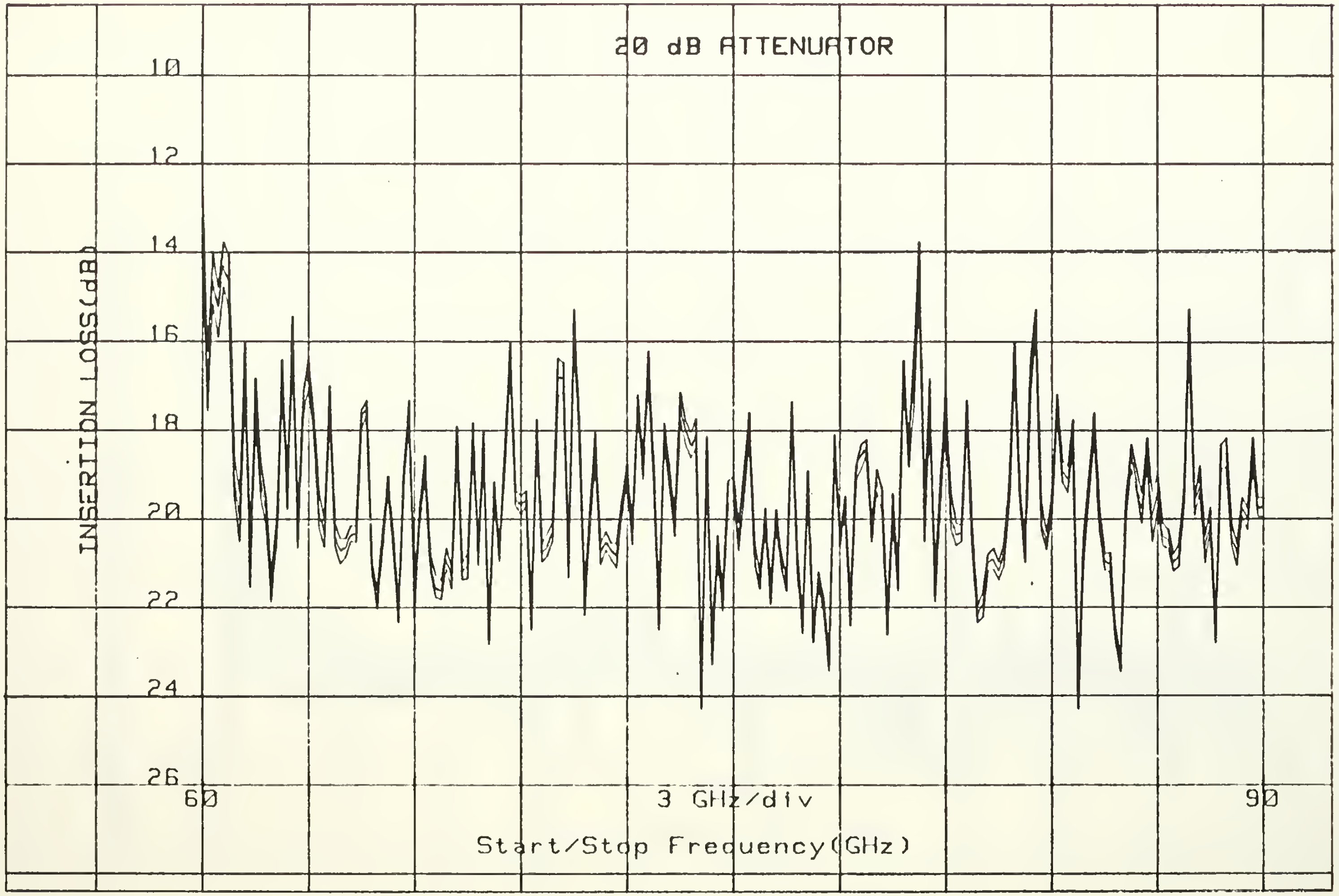


Figure 27. Insertion Loss for 20 dB Attenuator Using Whisker Diode Detector.

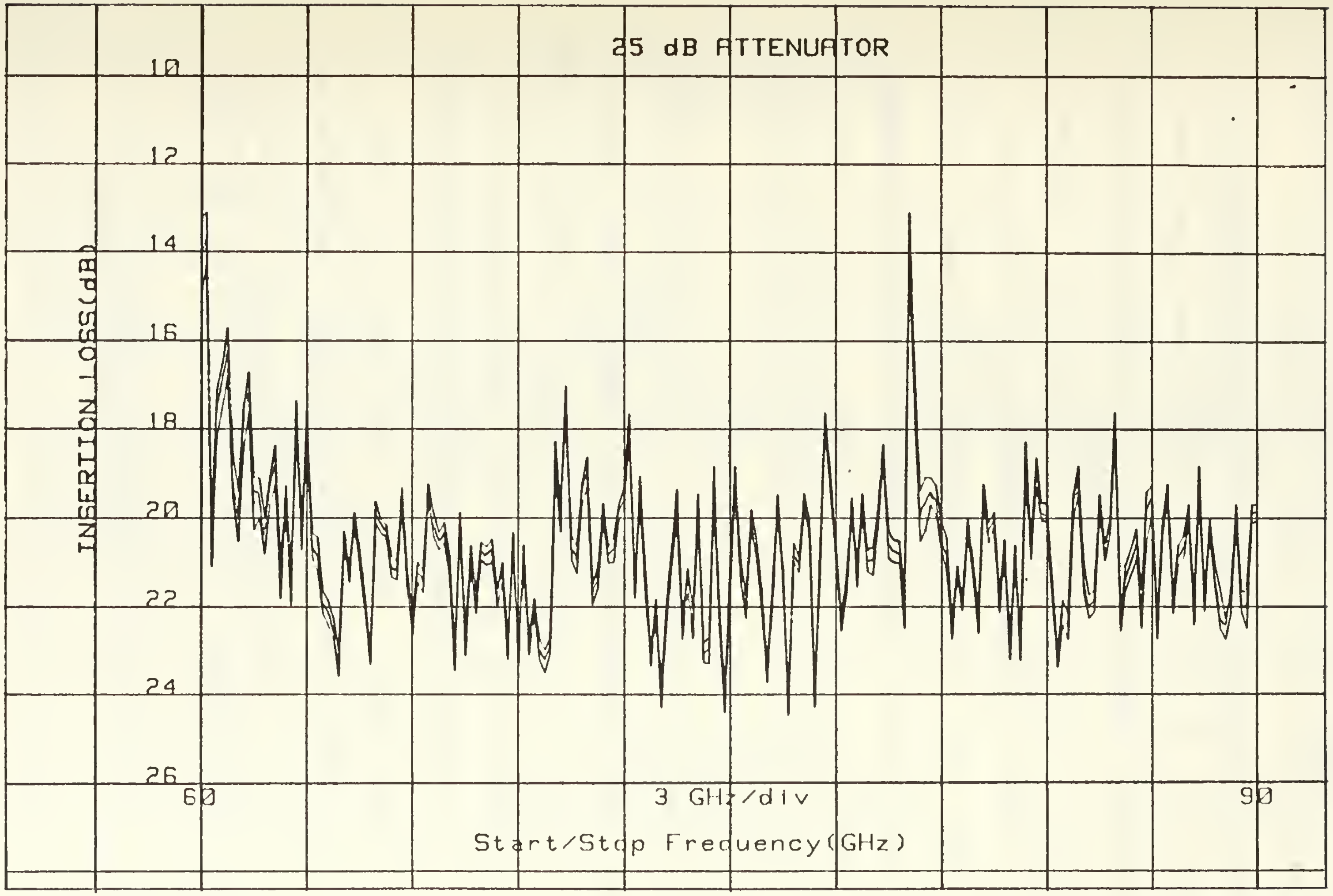


Figure 28. Insertion Loss for 25 dB Attenuator Using Whisker Diode Detector.

of the system. The solution, therefore, consisted of replacing the B detector and performing the insertion loss measurements without the A-coupler in the system.

Using this method insertion loss measurments for 0db, 10 dB, 20 dB, 30 dB, 40 dB and 45 dB were performed with the Schottky diode detector and the results given in Figures 29, 30, 31, 32, 33 and 34 respectively. Tabular results are found in Appendix C, Tables IX, X, XI, XII, XIII, and XIV. Once again the superior performance of the Schottky diode detector substantially increased the dynamic range although the accuracy did not seem as good. Figures 33 and 34 show a noise floor of about 40 dB which is double that of the whisker diode detector.

A phenomenon which appeared in the insertion loss measurements with the Schottky diode detector was a jump in insertion loss at the band-switch frequencies, 70 GHz and 80 GHz. At the band-switch frequencies the Sweep Oscillator Millimeter-Wave Plug-in commands the Full Band Sweep Source to select the next band rf source (See Figure 4). The Schottky diode detector would seem the likely candidate as the source of this discontinuity since the other detectors did not have this problem. Aside from the higher DC level of its output, however, the Schottky detector exhibits a square-law behavior with no indication that it changes

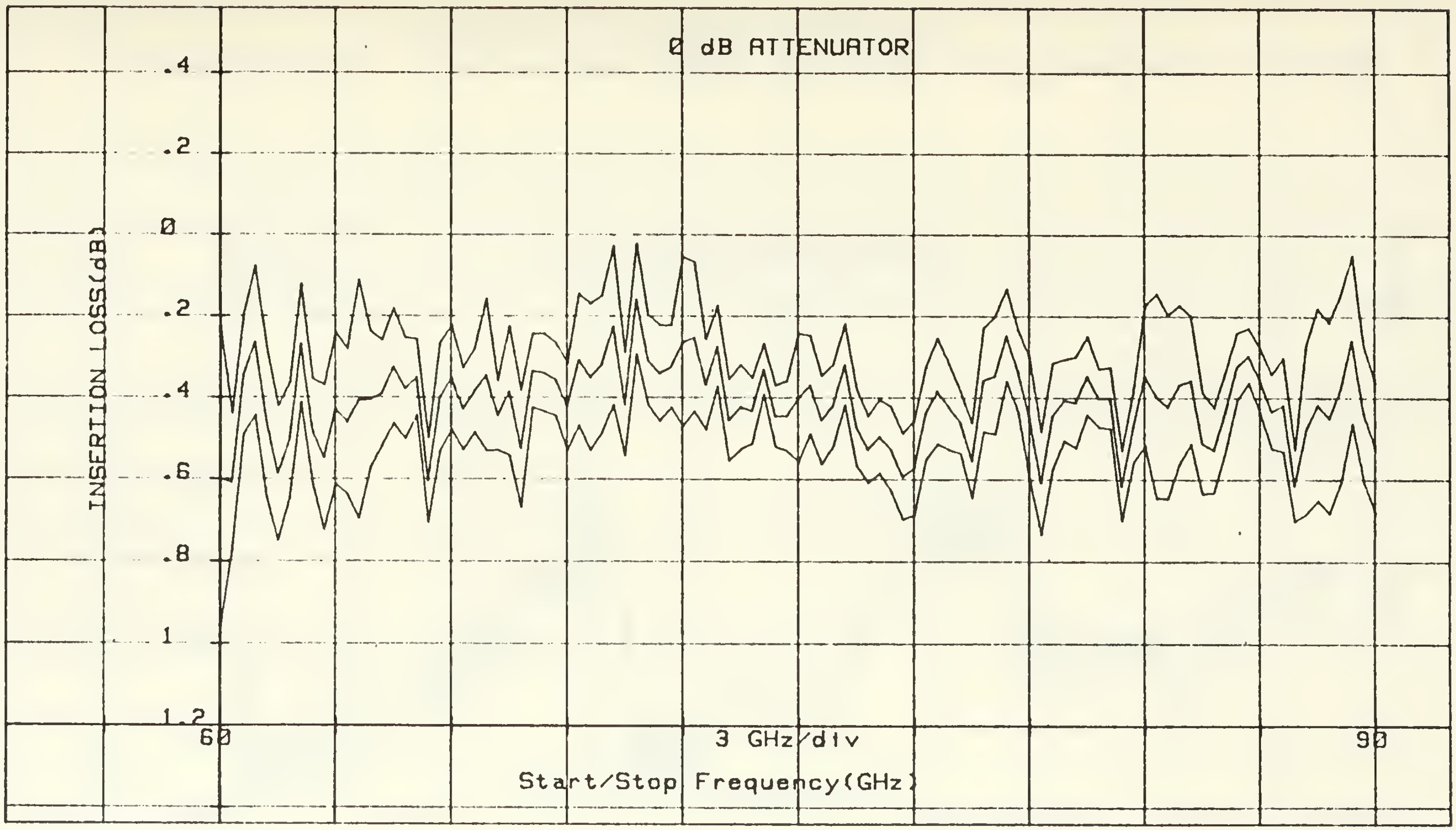


Figure 29. Insertion Loss for Ø dB Attenuator Using Schottky Diode Detector.

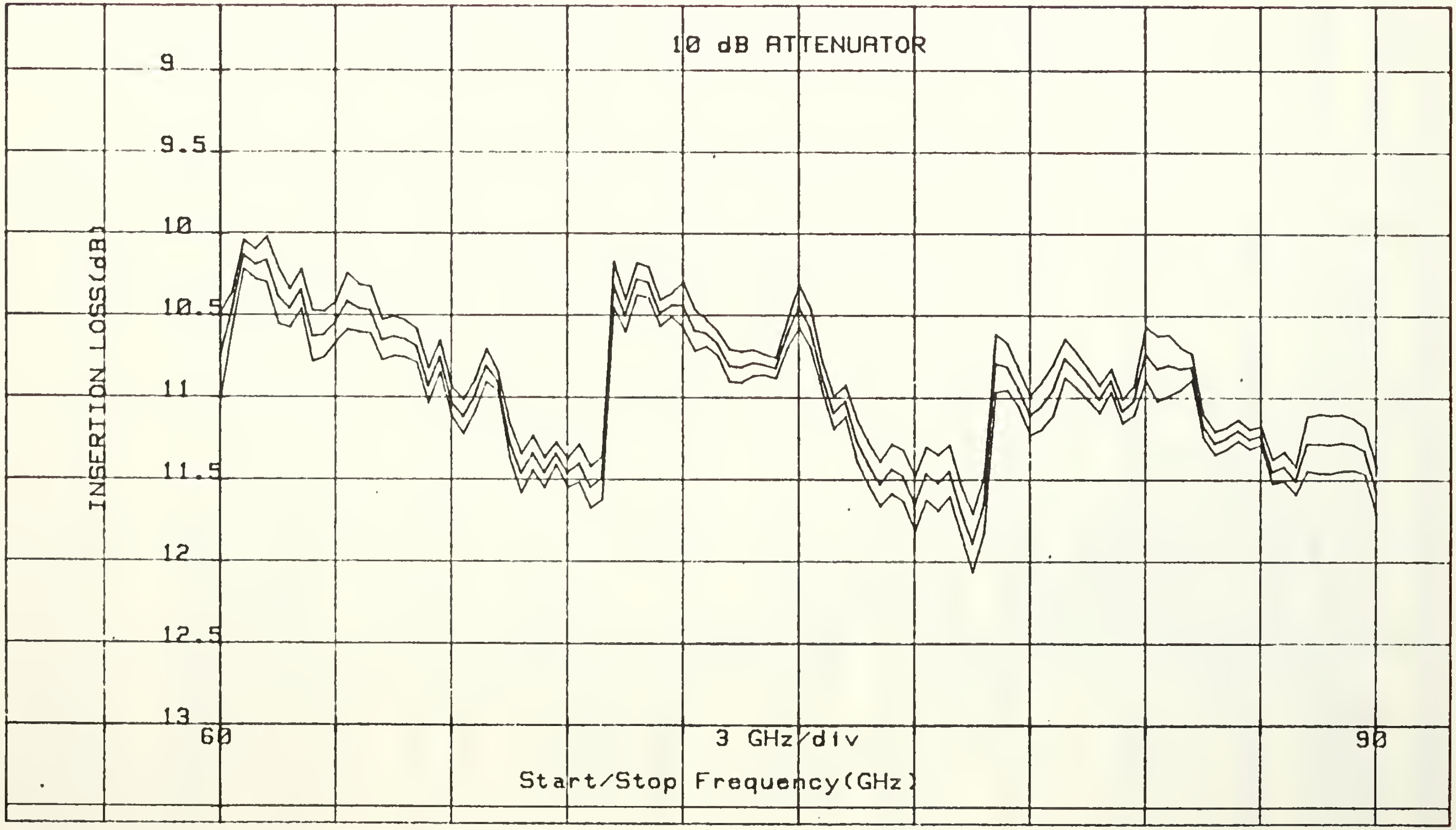


Figure 30. Insertion Loss for 10 dB Attenuator Using Schottky Diode Detector.

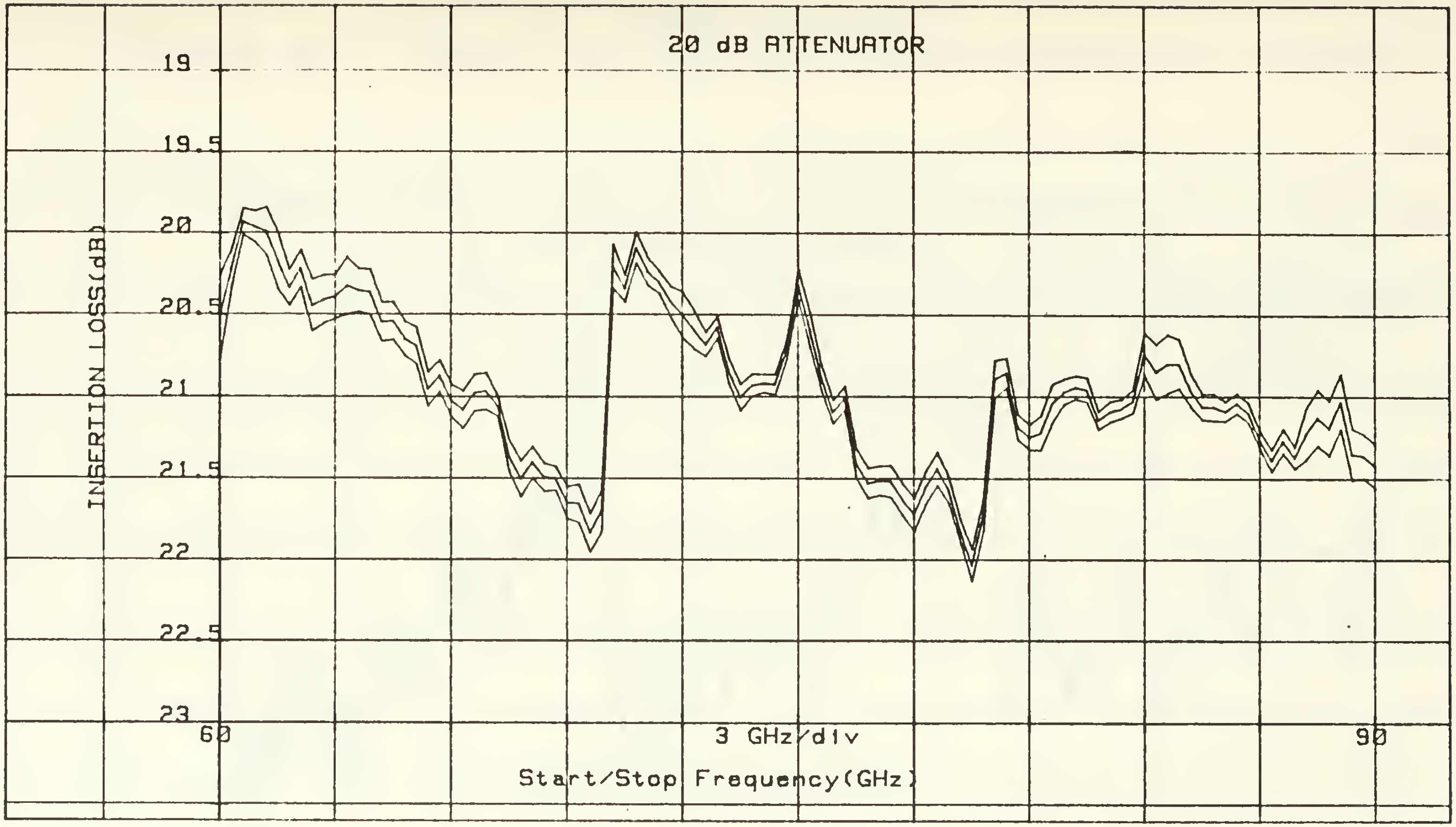


Figure 31. Insertion Loss for 20 dB Attenuator Using Schottky Diode Detector.

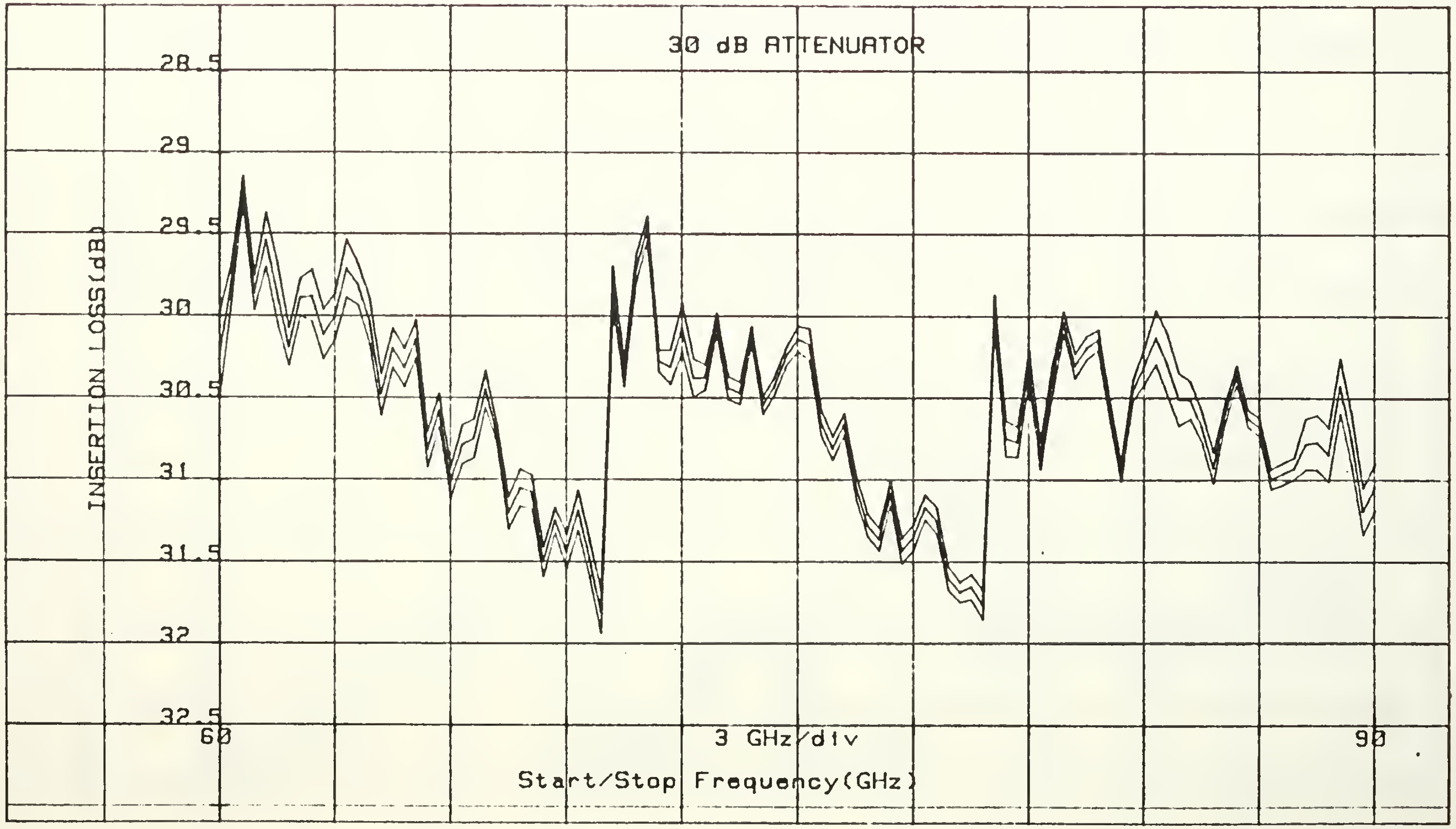


Figure 32. Insertion Loss for 30 dB Attenuator Using Schottky Diode Detector.

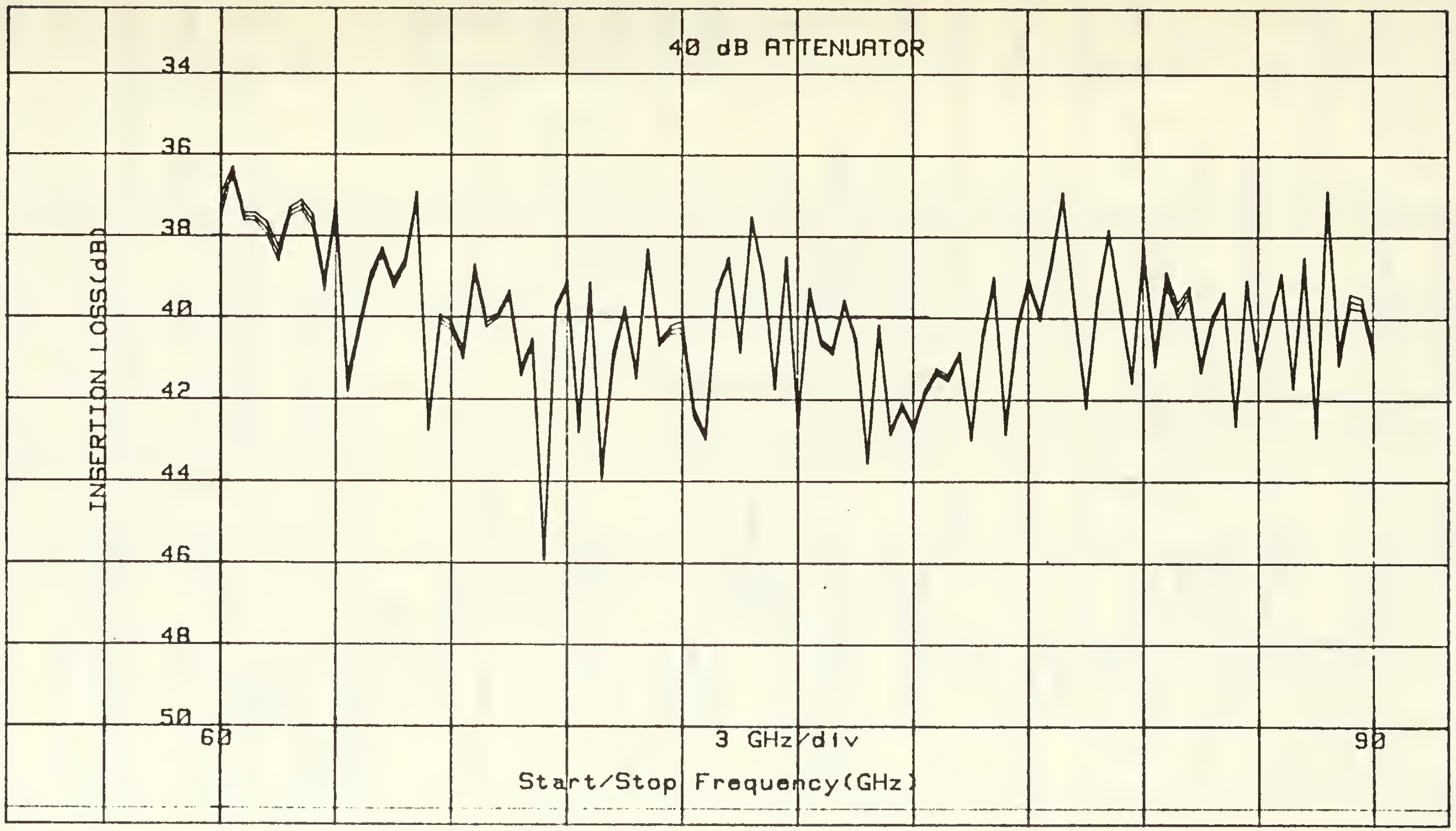


Figure 33. Insertion Loss for 40 dB Attenuator Using Schottky Diode Detector.

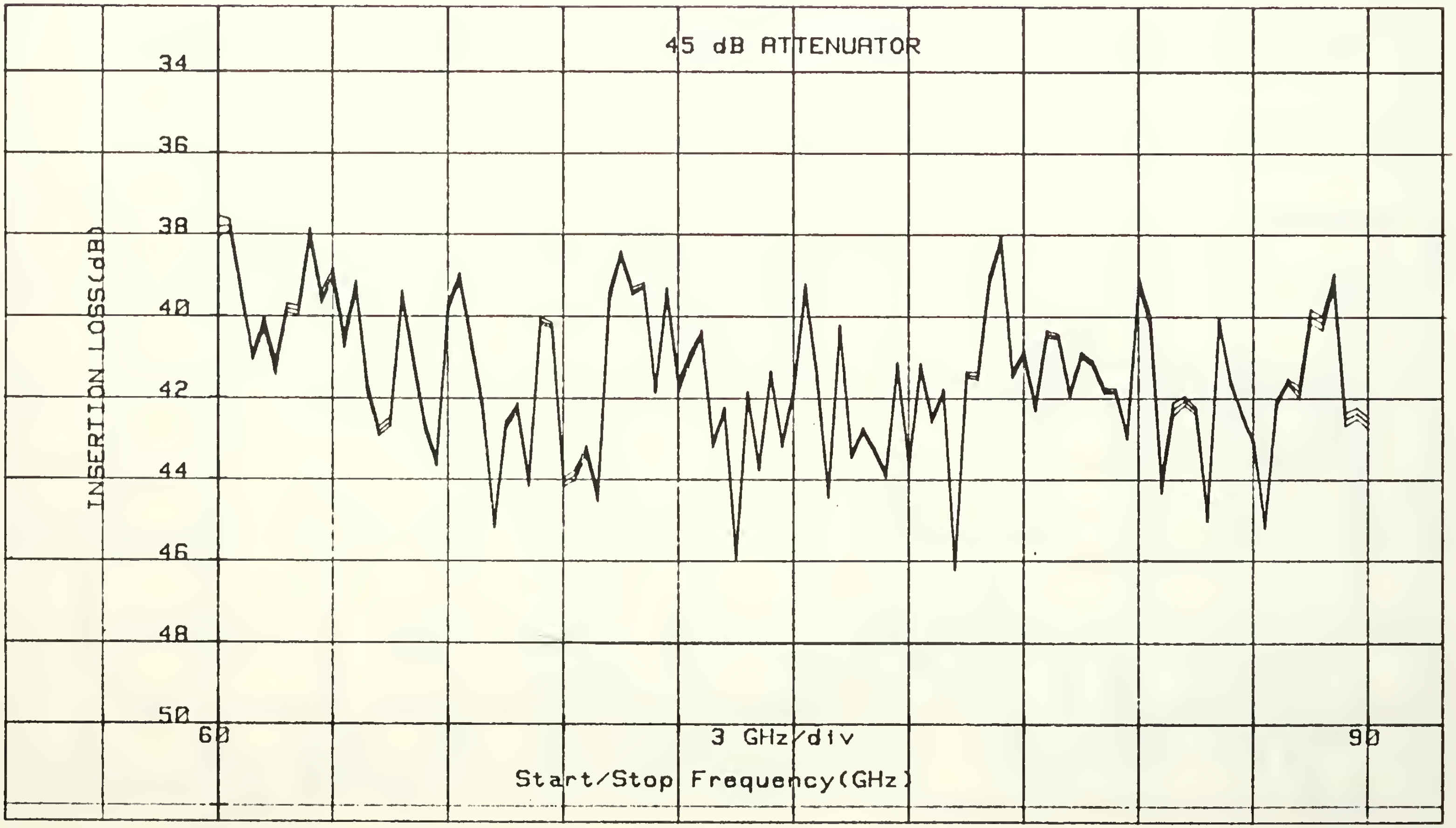


Figure 34. Insertion Loss for 45 dB Attenuator Using Schottky Diode Detector.

markedly at the band-switch points. It is unclear, therefore, what is causing the jumps in insertion loss at these points.

3. Dynamic Range

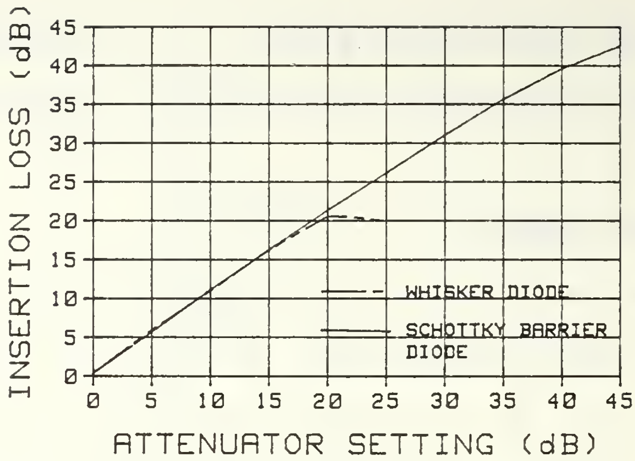
A graphical comparison of the dynamic range between the whisker diode detectors and the Schottky diode detectors is given in Figure 35. The performance of the Schottky diode detector is clearly better than that of the whisker diode and the system performance is comparible with that advertised by Hughes Aircraft Company [Ref. 2:pp. 24-25].

4. Comparison With Previous Theses Results

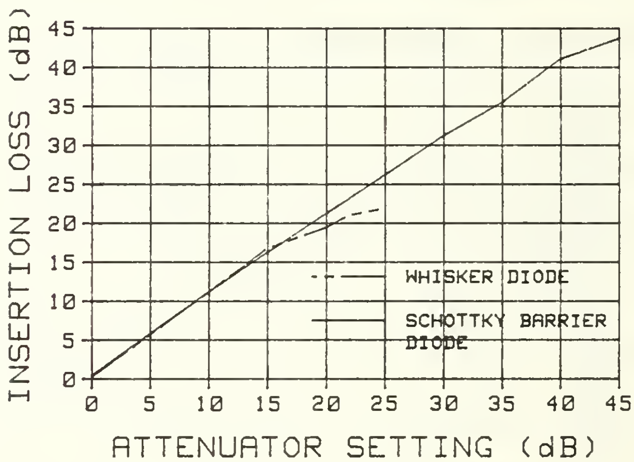
Previous theses measured a variety of devices and comparison of the old and improved systems provided excellent results. The first set of comparisons are from a thesis by George S. Leoussis, LT, Greek Navy [Ref. 1:pp. 37-38, 47-51]. It should be noted that the manufacturer of the devices measured by Leoussis were not specifically identified.

a. 10 dB Attenuator from 70 to 80 GHz

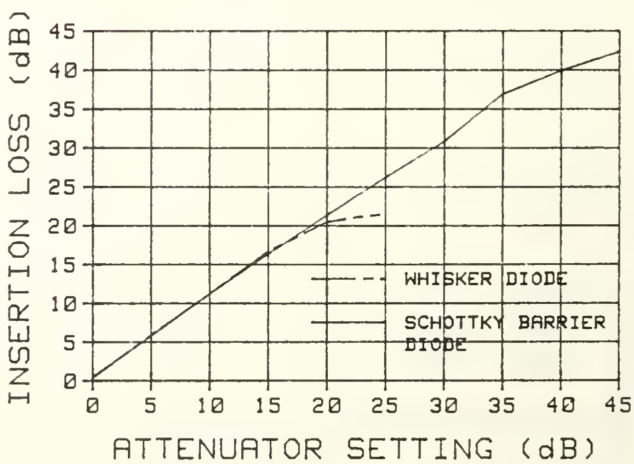
The comparison of insertion loss measurement for the old and improved systems are illustrated in Figure 36. Considering the expanded scale for the improved system measurement, the two measurements agree very well. It is interesting to note that in neither case was the measurement within the ±0.1 dB tolerance given by the manufacurer for the calibrated variable attenuator [Ref. 2:p. 35].



a. 65 GHz.

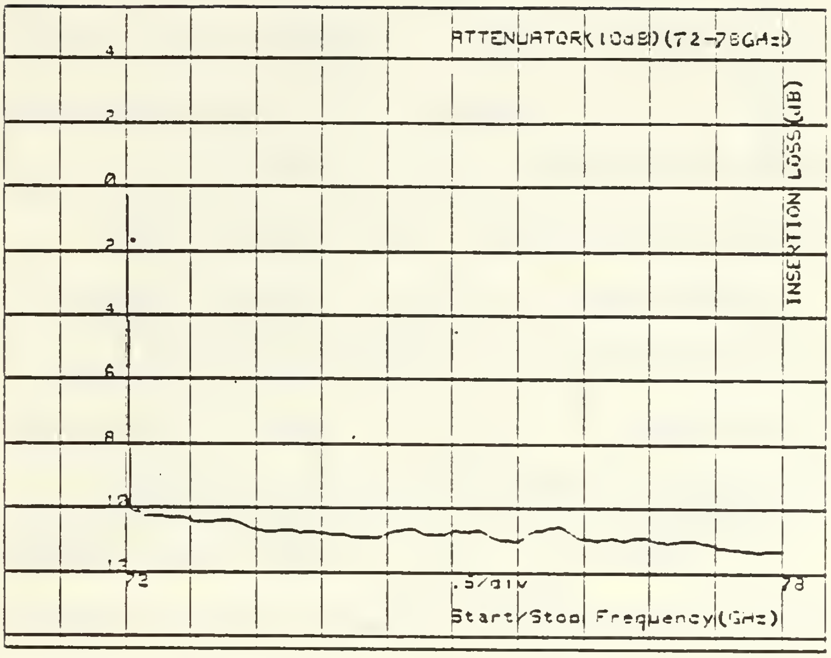


b. 75 GHz.

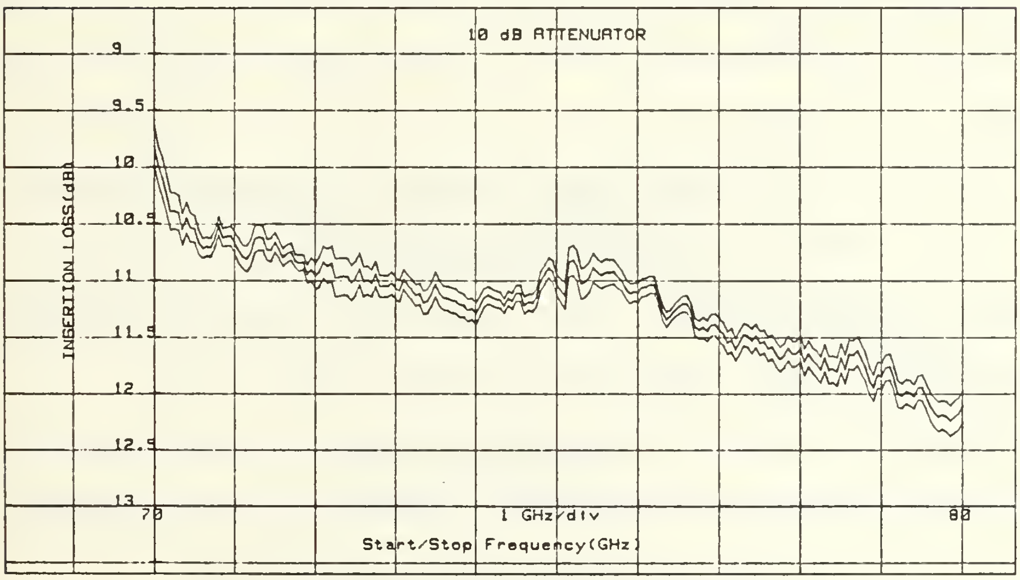


c. 85 GHz.

Figure 35. Dynamic Range for Insertion Loss.



a. Old System.



b. Improved System.

Figure 36. 10 dB Attenuator Insertion Loss Comparison from 70-80 GHz.

b. 20 dB Attenuator from 70 to 80 GHz

From Figure 37 one can see that the two systems are in close agreement again. Although the improved system appears to be a little closer to the set attenuation, once again neither measurement falls within the tolerance.

c. 30 dB Attenuator from 70 to 80 GHz

Comparison of the two systems remains consistant in Figure 38. The improved system appears closer to the attenuator tolerance but is still outside the range.

d. 40 dB Attenuator from 70 to 80 GHz

In Figure 39a the old system has encountered the maximum limit of its dynamic range at about 36 dB while the improved system is hovering around the set attenuation of 40 dB. The size of the excursions in Figure 39b indicate that the system was approaching its limit but there is no doubt that the improved system has a better performance at this level.

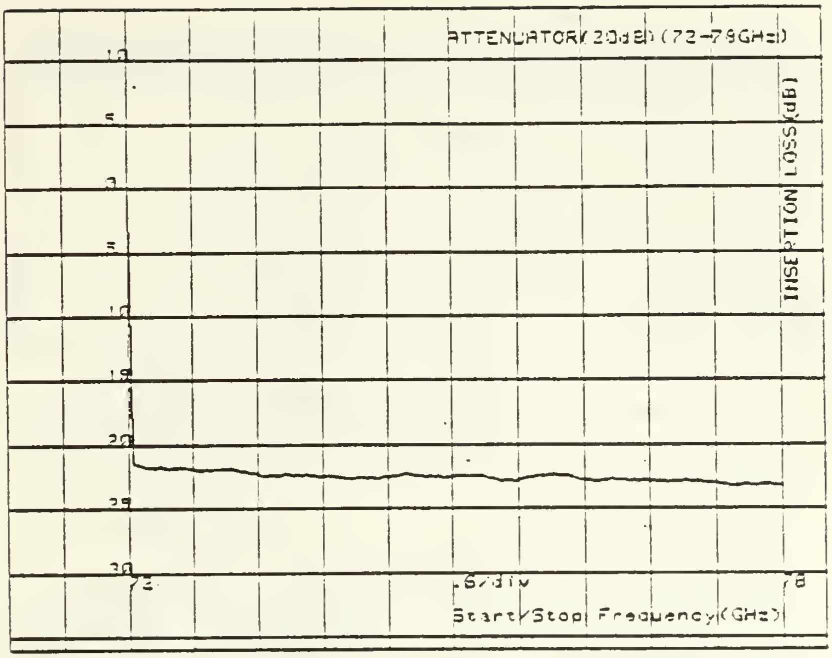
e. 10 dB Directional Coupler from 70 to 80 GHz

The correlation between the two systems in Figure 40 appears very close indicating that the two systems obtained the same insertion loss for this device.

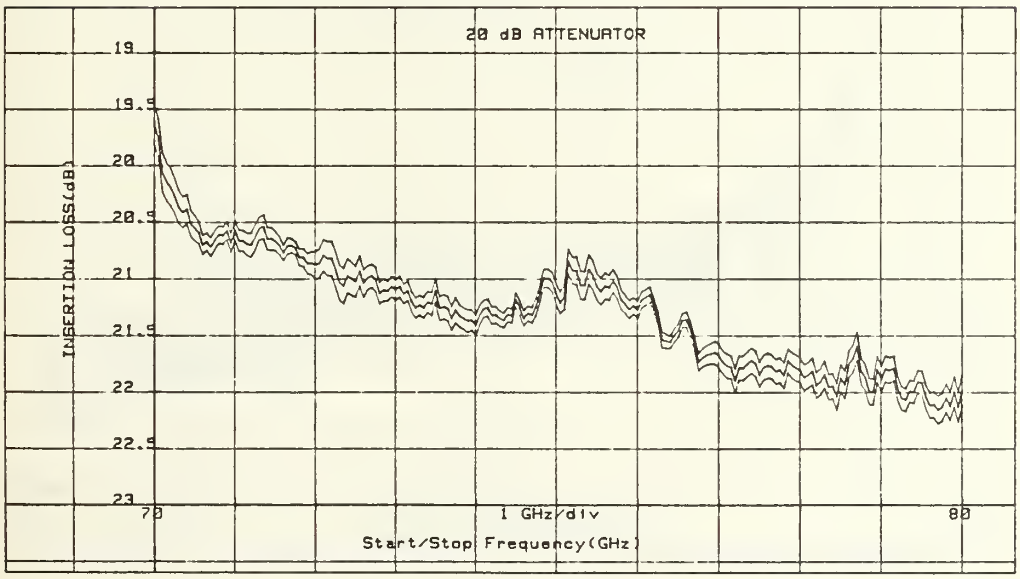
The next set of comparisons is from a thesis by Elia Demetrios Gatsos, LT, Greek Navy [Ref. 4:pp. 34, 53-60].

f. Through Section from 60 to 90 GHz

It was unclear from the thesis by Gatsos what the through section consisted of. From Figure 41a it would

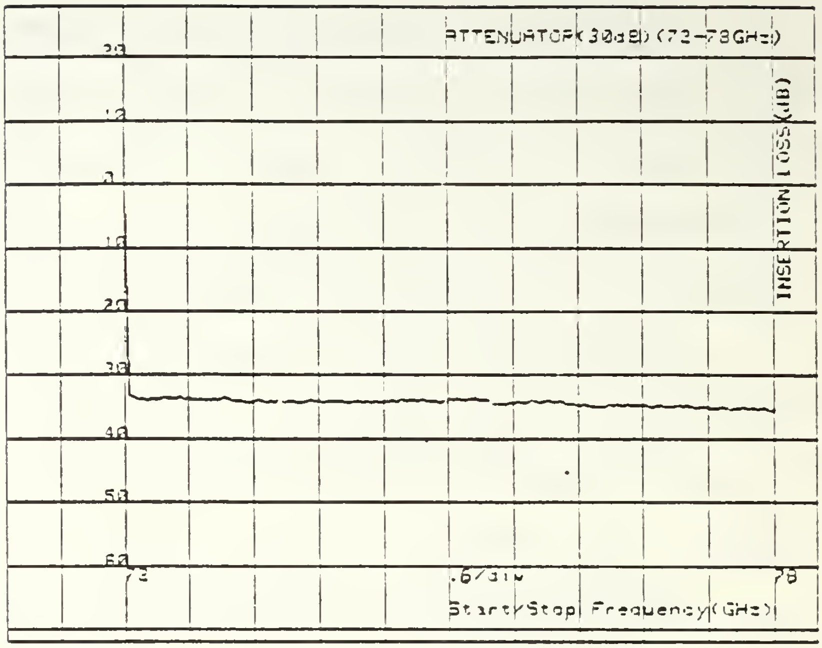


a. Old System.

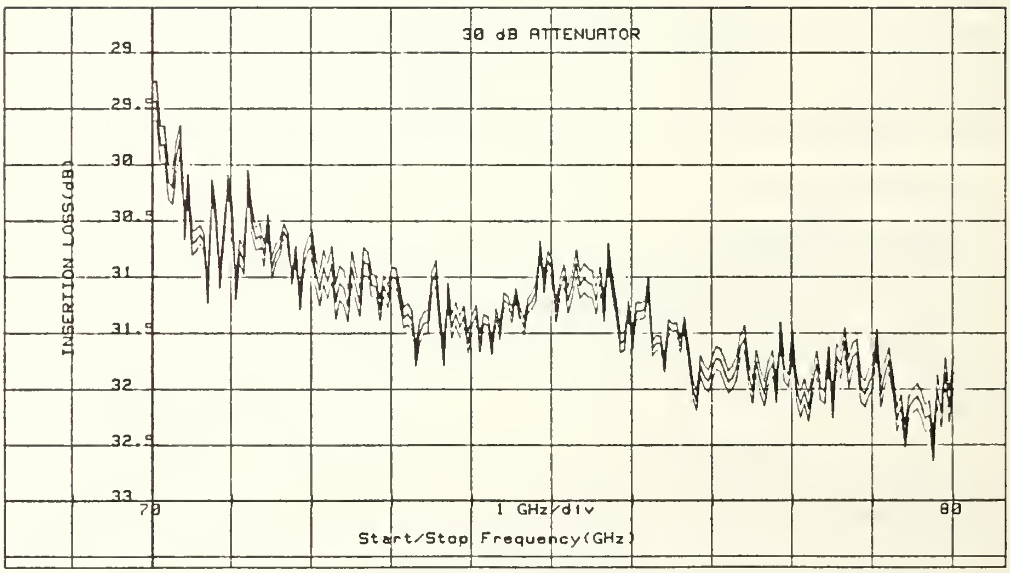


b. Improved System.

Figure 37. 20 dB Attenuator Insertion Loss Comparison from 70-80 GHz.

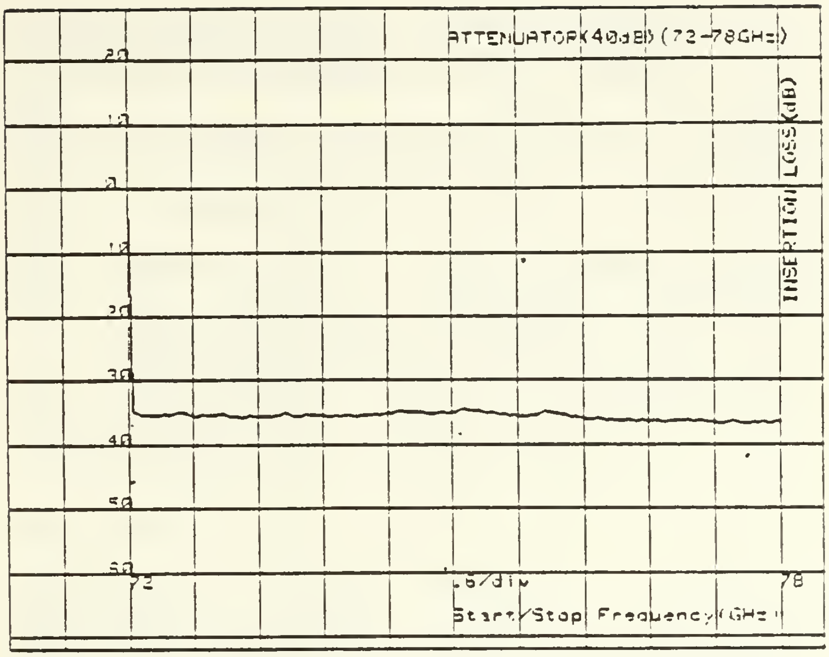


a. Old System.

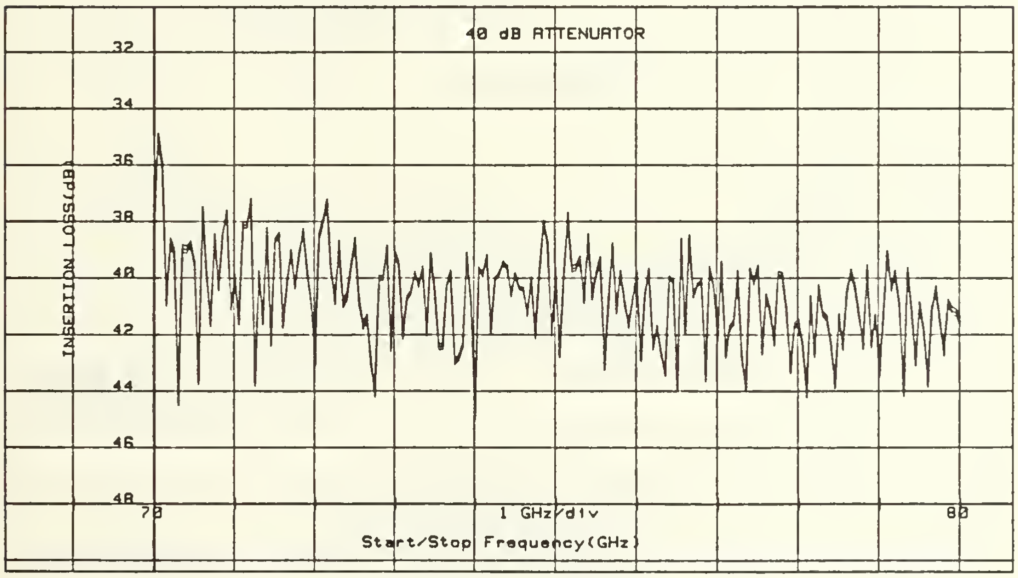


b. Improved System.

Figure 38. 30 dB Attenuator Insertion Loss Comparison from 70-80 GHz.

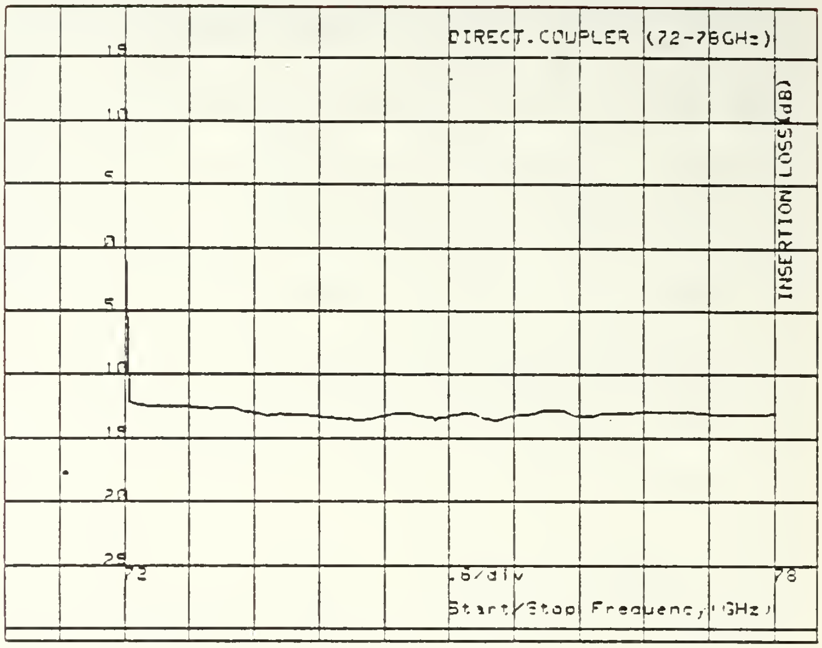


a. Old System.

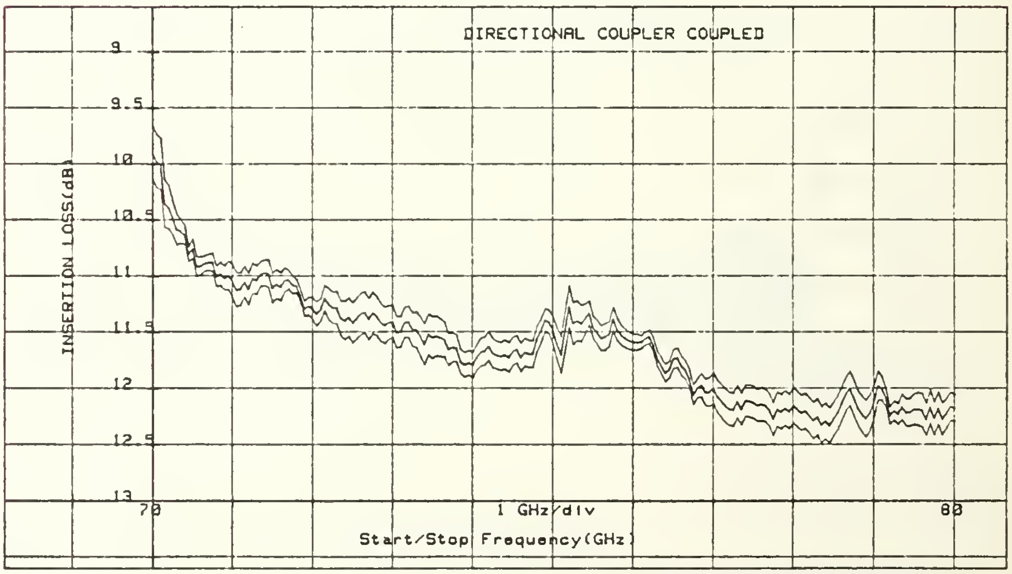


b. Improved System.

Figure 39. 40 dB Attenuator Insertion Loss Comparison from 70-80 GHz.

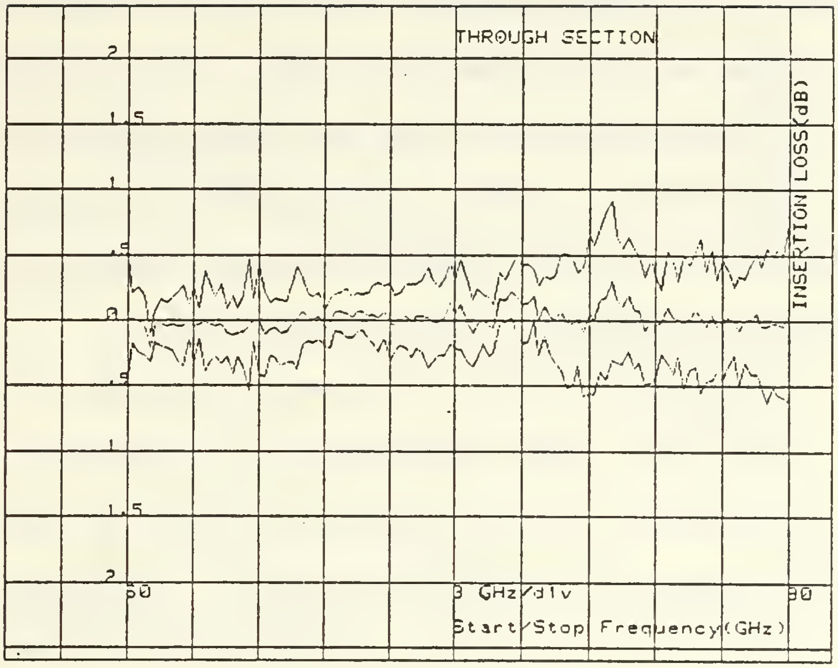


a. Old System.

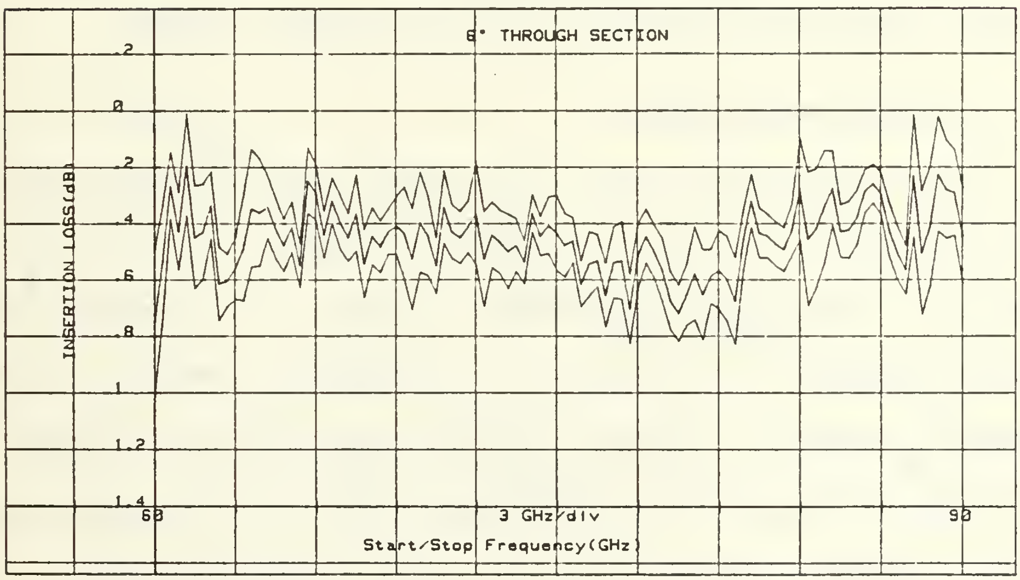


b. Improved System.

Figure 40. Directional Coupler Insertion Loss Comparison from 70-80 GHz.



a. Old System.



b. Improved System.

Figure 41. Through Section Insertion Loss Comparison from 60-90 GHz.

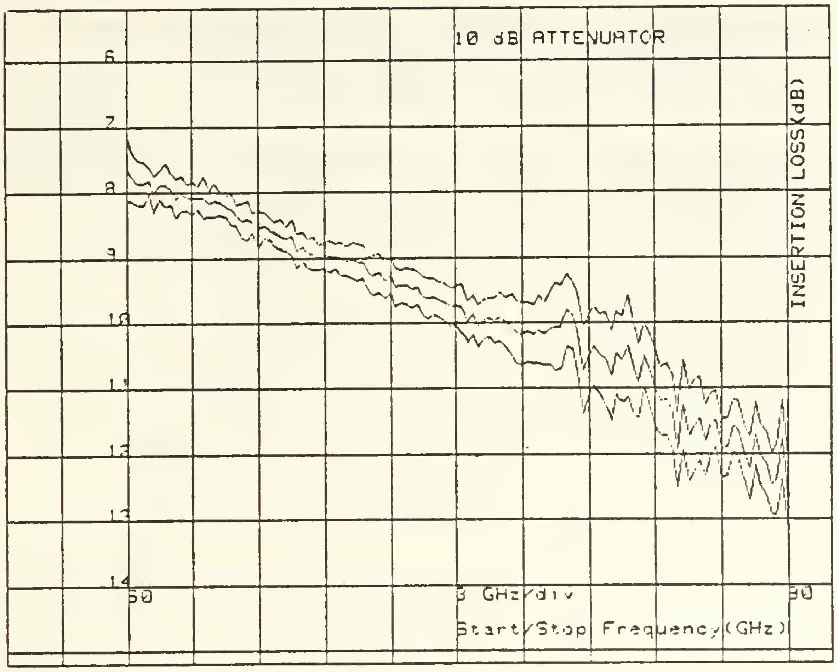
appear that the through section was of zero length since the insertion loss was approximately 0 dB. For the improved system, a 6 inch through section was used. The typical loss of E-band waveguide is about 1 dB/ft. As one can see from Figure 41b, the insertion loss measurement hovers around 0.5 dB, the expected value of the insertion loss.

g. Baytron Variable Attenuator from 60 to 90 GHz.

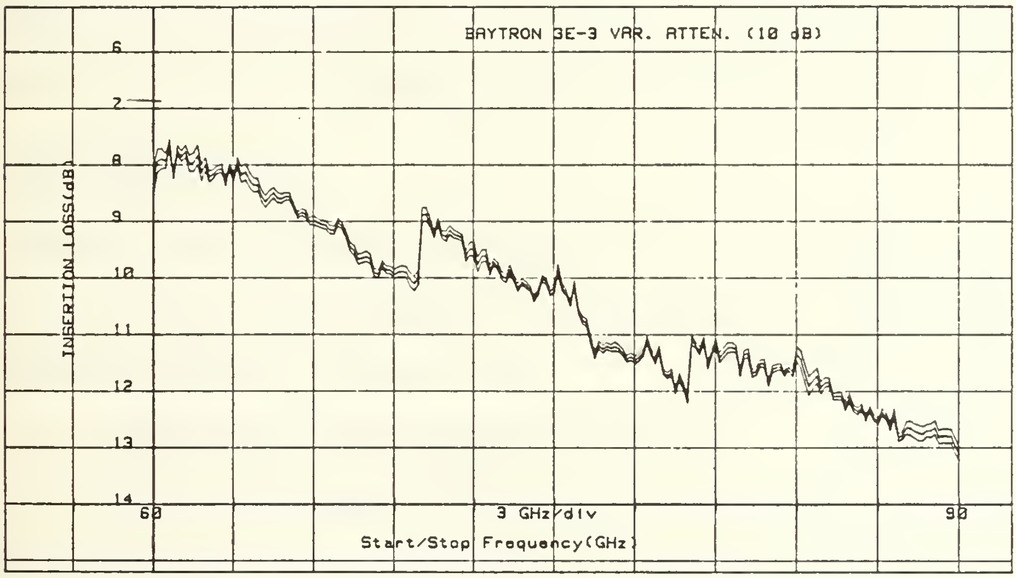
The full band comparison of the Baytron 3E-3 Variable Attenuator set at 10 dB can be seen in Figure 42. Despite the rather poor performance of the attenuator, the range of insertion loss values from 60 to 90 GHz between the two systems agree very well. The attenuator is calibrated for a correct reading at 75 GHz. Both systems came very close to this reading although the improved system appeared closer and the uncertainty range was much tighter.

C. PLOTTER PERFORMANCE

One of the major improvements to the Millimeter-Wave Scalar Network Analyzer system was the ability to produce a graphical output on the HP-9872 Plotter. In the previous comparisons the old outputs were produced from the HP-9845B Computer internal thermal printer while the new outputs were produced on the HP-9872C Plotter. The plotter outputs are significantly clearer with excellent resolution and contrast. By using the plotter the user can also vary the size of the output and use different colored pens to enhance



a. Old System.



b. Improved System.

Figure 42. Baytron Variable Attenuator Insertion Loss Comparison at 10 dB from 60-90 GHz.

the graphical output. Neither of these features were available with the internal thermal printer. Some programming knowledge would be necessary to change the existing parameters in the "MMWSNA" program.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The Improved Millimeter-Wave Scalar Network Analyzer exhibits better overall performance than its predecessor. The addition of the Schottky barrier diode detector and the HP-8756A Scalar Network Analyzer provides a dynamic range which rivals industry standards.. Software modification and computer control of the HP-8350B Sweeper Controller and the HP-8756A Scalar Network Analyzer has reduced user interface and speeded up the measurement process. By providing all of the previous output capabilities as well as the HP-9872C Plotter output, the system is able to give the user a maximum amount of clear data for analysis. The system is composed of off-the-shelf components so anyone desiring such a system is able to obtain the necessary equipment.

B. RECOMMENDATIONS

Despite this system's improved performance over any previous system, some system improvements can still be made and some anomalies looked into.

1. Schottky Barrier Diode Detectors

The performance of this diode detector is excellent and it is recommended that the A, B and R couplers be fitted with these detectors. This will ensure peak performance and maximum user friendliness for insertion loss measurements.

2. Measurement Accuracy

Both the return loss and insertion loss measurement accuracies were 1-2 dB above the maximum rated tolerance of the calibrated variable attenuator which was used. Some of the device measurements, however were exactly where one would expect them to be (Baytron Attenuator and the Through Section). It is not obvious where the source of this anomaly is and further investigation is in order.

3. Band Switch Jumps

In the insertion loss measurements, significant jumps in dB level occur at the band switch frequencies of 70 and 80 GHz. It is unclear why these discontinuities occur and further investigation into the problem and its solution should be pursued.

4. Maximum Uncertainty Calculation

As was discussed in Chapter III, the maximum uncertainty of high return loss devices sometimes becomes uncalculable because the computation only takes into consideration the worst case coupler directivity. The plot may be more meaningful if the actual coupler directivity could be determined for each of the test frequencies and this value entered into the maximum uncertainty calculation. Another approach might be to investigate an equivalent expression for computing the uncertainty which would prevent forbidden function arguments from occurring.

5. <u>Plotter Parameters</u>

Currently the only plotter in the program is the HP-9872 series. The parameters as to graph size and pen number has been entered into the computer code and can only be changed by altering the code. The program could be enhanced by prompting the user with a number of possible plotter selections as well as providing the user with the ability to determine the graph size and orientation and allowing the user to select which pen is to be used for the grid, labels, measurement plot, uncertainty plots, etc.

APPENDIX A

USER'S GUIDE

A. SYSTEM CONNECTIONS

1. HP-IB should connect the HP-9845B Computer, HP-9872C Plotter and HP-8756A Scalar Network Analyzer.
2. The system bus should connect the HP-8756A Scalar Network Analyzer and the HP-8350B Sweeper Controller.
3. Ensure that the Hughes Millimeter-Wave Plug-In is properly seated in the HP-8350B adapter and the ROM modification installed, and that the unit is seated in the Sweeper Controller. Make Reflectometer connections to the front of the Plug-In.

B. SYSTEM START-UP

Once all connections are made turn on the units. Default selections will be initiated on the Sweeper Controller and the Scalar Network Analyzer. These values need not be changed as the program will take care of this later.

C. SYSTEM INITIALIZATION

1. Load the program from either disk or tape.
2. Press RUN.
3. The computer will display the soft key menu for output and the operator has the following options:

a. Using the key number six (K6), the operator can read previously obtained and stored data from the disk or tape. By pressing K6 the computer asks the operator if he wants data from the Disk (D) or Tape (C) and he can select either one and press CONT. Wrong choices will result in a continued prompt for an acceptable choice. The computer will then prompt for the name of the data file. Enter the name and press CONT. The computer reads the data from the file and then returns to the soft key menu. The operator may now either DISPLAY (K2) or PRINT (K3) the data.

b. Using the key K0, SELECT TYPE OF MEASUREMENT, the operator can select any particular measurement he wants by pressing:

K1 Insertion Loss

K2 Return Loss

K3 Both.

c. Once the selection of measurement is made the operator then enters the "DATA ENTRY" routine. The computer will ask the following:

(1) START frequency (GHz)

(2) STOP frequency (GHz)

A WARNING may come up at this point which is addressed in Chapter II, Section 4. The program

will allow the operator to reenter the START/ STOP frequencies or the operator may continue.

(3) A menu of the number of data points desired for the measurement is then presented and the operator enters the appropriate letter. The number of data points may <u>not</u> be changed without RESTARTING the program.

At this point the system is initialized and the program goes to the measurement subroutine selected.

D. RETURN LOSS MEASUREMENTS

1. The calibration routine is executed first. The operator is prompted to connect the adjustable short and press CONT. Refer to Figure 2a for the connection with the sliding short as the DUT. As the program is executed the operator is prompted to move the sliding short to 10 different positions. It is recommended that the operator move the sliding short from its minimum position to its maximum position in 10 equal steps ensuring that the length of travel exceeds 2.5 mm to allow proper computation of the maximum and minimum calibration averages.
2. The program now executes the Device measurement subroutine, the operator connects the DUT and labels it (up to 32 characters).

3. Once the measurement is made the soft key main menu comes up and the operator may now select an appropriate output (See OUTPUT section).

E. INSERTION LOSS MEASUREMENTS

1. The operator is first asked if the A-coupler will be removed during the Insertion Loss calibration or measurement which he must answer "Y" for yes or "N" for no.
2. The program first executes the Return Loss Calibration if it has not done so already (Refer to Section D1).
3. The program will ask the operator to connect the B-coupler and the reflection coefficient of the B-coupler will be measured, $|\Gamma_L|$.
4. The software will ask the operator to connect the DUT and its input reflection coefficient will be measured (S_{11}^{DUT}) followed by the output reflection coefficient measurement (S_{22}^{DUT}). In both cases the maximum reflection coefficient will be evaluated using the value of $|S_{22}|$ from the calibration data.
5. Based on whether or not the A-coupler is present, the program will now compute the value of $|\Gamma_S|$. The program then executes the Insertion Loss Calibration Average subroutine and the value of the calibration

average (Through) is measured. No operator input is needed for this step.

6. The device under test is now inserted and the $|S_{12}^{DUT}|$ is measured followed by the measurement of the $|S_{21}^{DUT}|$ which is in fact the Device Measurement.

7. The operator will now label the device and upon pressing CONT the program will return to the soft key main menu for output selection.

F. OUTPUT

1. The following options are available from the soft key menu for the output:

   a. K1 PLOT DATA. The computer executes successively the subroutines Initialize, Compute scale, Label scale, Label frequency, Label device, Label loss and Plot data. At this point the operator may choose to output the graph to the internal thermal printer (Press "P"), to the HP-9872 Plotter (after placing paper in the "landscape" position and pressing "Q") or returning to the soft key menu by pressing CONT.

   b. K2 DISPLAY DATA. The computer executes the display data subroutine. Eleven lines are

displayed each time the operator presses the CONT key.

c. K3 PRINT DATA. The computer executes the print data subroutine, data are printed and the program resumes the soft key main menu.

d. K7 PRINT INTERMEDIATE VALUES - INSERTION. The operator has two options:

(1) DISPLAY DATA (K7, CONT)

(2) PRINT DATA (K7, Y, CONT)

Note that since these values are the same and independent of the DUT one copy of them is needed. The values which are presented are:

(1) $|S_{21}|^{DUT}$

(2) $|S_{12}|^{DUT}$

(3) $|S_{11}|^{DUT}{}_{MAX}$

(4) $|S_{22}|^{DUT}{}_{MAX}$

(5) $|\Gamma_s'|$

(6) $|\Gamma_L'|$

(7) Avg. = Insertion loss Calibration Average (Through).

e. K9 PRINT INTERMEDIATE VALUES - RETURN LOSS. The operator has two options:

(1) DISPLAY DATA (K9, CONT)

(2) PRINT DATA (K9, Y, CONT)

Note that since these values are the same and independent of the DUT one copy of them

is needed. The values which are presented are:

(1) R1(X) = Maximum Calibration Average

(2) R2(X) = Minimum Calibration Average

(3) R(X) = Calibration Average

(4) R6(X) = S_{22} of Calibration Data.

f. K5 STORE DATA TO A DISK OR CASSETTE. The program executes the disk storage subroutine. The operator has two options:

(1) Store data into a disk (K5, D, CONT, FILE NAME, CONT), here mass storage is ":Fn".

(2) Store data into a cassette (K5, C, CONT, FILE NAME, CONT), mass storage is ":Tn (default is T15).

Disk storage is preferred since access time is less on disk. The operator can use up to six (6) characters to name the file and care must be taken here to avoid duplicate file names. Regardless of the file name, the original DUT label will remain the same. After data storage the program returns to the soft key main menu.

g. K4 NEXT MEASUREMENT. The program executes the Device measurement subroutine. The same calibration data will be used for any DUT at the same frequency range. The operator

should insert the new DUT and then press the CONT key. The Return Loss and/or Insertion Loss subroutines will be followed minus the calibration portions (D1 and E2,3).

h. K8 RESTART. The program resumes the TYPE OF MEASUREMENT menu for a completely new measurement beginning at C3b of the Users Guide.

APPENDIX B

PROGRAM LISTING AND VARIABLES

A. PROGRAM LISTING

The program used for the improved Millimeter-Wave Scalar Network Analyzer is "MMWSNA". This program is available on Hewlett Packard 8-1/2" single sided floppy disk or on HP tape and a listing is provided at the end of this Appendix.

B. LIST OF VARIABLES

The variables used for the "MMWSNA" program along with their definition are as follows:

A	- Start frequency (GHz)
A0	- HP-8756A Scalar Network Analyzer address
A$	- Temporary string variable
B	- Stop frequency (GHz)
B$	- Data storage device type
C	- Band sweep time (msec)
D(X)	- Data points for loss computation
D1(X)	- Temporary variable for low-band data points
D2(X)	- Temporary variable for mid-band data points
D3(X)	- Temporary variable for high-band data points
D10(X,Y)	- Return loss calibration data points
F	- Data point frequency for printout
F1	- Mid-band measurement flag

F2	- High-band measurement flag
F5	- Frequency START/STOP warning flag
F$	- Data file name
H	- Insertion Loss Calibration Flag
H1	- Return Loss Calibration Flag
I	- Loop variable
I$	- Temporary string variable
J	- Loop variable
K	- Maximum calibration average in dB for printout
L	- Minimum calibration average in dB for printout
M3	- Total plot range (dB)
M4	- Maximum plot value (dB)
M5	- Intermediate plot markings
M6	- Linear Average of the Maximum and Minimum Loss (dB)
M7	- Temporary variable for computing maximum value of plotting scale
M8	- Maximum Loss (dB)
M9	- Minimum Loss (dB)
N	- Mode (1=Insertion, 2=Return, 3=Both)
N1	- Plotting flag for Insertion Loss
N$	- Label for DUT
P	- Step counter based on number of data points
P0	- HP-9872 Plotter address
P1	- Maximum value for plotting loop

P$	- Label for type of loss
R(X)	- Linear average of the calibration maximum and minimum
R1(X)	- Maximum calibration average
R2(X)	- Minimum calibration average
R3(X)	- Uncertainty of Return Loss
R4(X)	- Maximum value of Return Loss
R5(X)	- Minimum value of Return Loss
R6(X)	- S_{22} of calibration data
R7(X)	- Uncertainty of S_{22}^{DUT} measurement
R8(X)	- Uncertainty of S_{22}^{DUT} measurement
R9(X)	- DUT input reflection coefficient
R10(X)	- S_{12}^{DUT}
R11(X)	- S_{21}^{DUT} and Insertion Loss
R12(X)	- Maximum value of Insertion Loss
R13(X)	- Γ_L'
R14(X)	- Γ_s'
R15(X)	- Insertion Loss Calibration Average
R16(X)	- Minimum value of Insertion Loss
R17(X)	- Maximum value of S_{11}^{DUT}
R18(X)	- Maximum value of S_{22}^{DUT}
R19(X)	- Return Loss
S0	- HP-8350B Sweeper Controller address
S1	- Band start frequency
S2	- Band stop frequency
W	- Loop variable

X	- Loop variable
X1	- Loop variable
X2	- Loop variable
Y	- Data point index counter
Z	- S_{21}^{DUT} in dB for printout

PROGRAM LISTING

```
10  !
20  ! ****************  M M W S N A  ***********************
30  !
40  !
50  ! This program was developed by David E. Falkner, LT, USN.
60  ! It is a modification of the "AEK" PROGRAM developed by
70  ! ELIA GATSOS (LT) HELLENIC NAVY
80  ! The features of this PROGRAM are :
90  ! RETURN and/or INSERTION LOSS MEASUREMENTS,
100 ! COMPUTATION of RETURN and INSERTION LOSS UNCERTAINTIES,
110 ! DISPLAY , PRINT , STORE , READ  of all parameters involved,
120 ! PLOTTING of results on either the HP-9845 thermal printer
130 !     or the HP-9872 plotter.
140 ! This set up uses:
150 !   (a)HP-8350B SWEEP OSCILLATOR with HUGHES 60-90 GHz Plug-in,
160 !   (b)HP-8756A SCALAR NETWORK ANALYZER,
170 !   (c)HP-9845B COMPUTER,
180 !   (d)HP-9872C PLOTTER.
190 !
200 ! *************  MAIN PROGRAM  **********************
210 !
220   GOTO 340
230 GOSUB 720 ! INITIALIZE
240 GOSUB 910 ! PLUG-IN
250 GOSUB 990 ! START/STOP
260   H1=0
270 IF N<>1 THEN GOSUB 1810! RETURN LOSS CALIBRATION
280 IF N<>1 THEN GOSUB 3970! MEASURE RETURN LOSS
290 IF N<>2 THEN GOSUB 2250! INSERTION LOSS MEASUREMENT
300 IF N=1 THEN GOSUB 4020
310 !
320 ! Soft-key menu for output
330 !
340 BEEP
350 DISP
360 GCLEAR
370 PRINT PAGE
380 PRINT LIN(16),CHR$(131);"SELECT FUNCTION:";CHR$(128)
390 PRINT
400 PRINT
410 PRINT "k0:Select type of Measurement(INSERTION,REFLECTION,BOTH)"
420 PRINT
430 PRINT "k1:PLOT data k2:DISPLAY data k3:PRINT data k4:NEXT meas k8:RESTART"
440 PRINT
450 PRINT "k5:STORE data to DISK or TAPE  k6:READ data from DISK or TAPE "
460 PRINT
470 PRINT "K7:Display intermediate values for INSERTION "
480 PRINT
490 PRINT "k9:Display intermediate values for REFLECTION "
500 PRINT
510 ON KEY #0 GOTO 230
520 ON KEY #1 GOTO 4360
530 ON KEY #2 GOTO 5850
540 ON KEY #3 GOTO 6190
550 ON KEY #4 GOTO 280
560 ON KEY #5 GOTO 7620
570 ON KEY #6 GOTO 7850
580 ON KEY #7 GOTO 8040
590 ON KEY #8 GOTO 620
600 ON KEY #9 GOTO 8510
610 GOTO 610
620 OFF KEY #4
630 OFF KEY #8
640 GOTO 230
650 !
660 !
```

```
670 !    SUBROUTINES
680 !
690 !
700 !    INITIALIZE
710 !
720 OPTION BASE 1
730 COM S$[32],P$[24],SHORT D(401),N$[32]
740 SHORT R(401),R1(401),R2(401),R3(401),R4(401),R5(401),R6(401),R7(401),R8(401)
750 SHORT R9(401),R10(401),R11(401),R12(401),R13(401),R14(401),R15(401),P16(401)
760 SHORT R17(401),R18(401),R19(401)
770 SET TIMEOUT 7;5000
780 ABORTIO 7
790 CLEAR 7
800 LOCAL 7
810 REMOTE 7
820 S0=717 !8350B SWEEPER select
830 A0=716 !8756A NETWORK ANALYZER select
840 P0=705 !9872C PLOTTER select
850 PRINTER IS 16
860 H=0
870 RETURN
880 !
890 !    <PLUG-IN BAND LIMITS>
900 !
910 RESTORE 940
920 READ L
930 READ U
940 DATA 60,90
950 RETURN
960 !
970 !    <DATA ENTRY>
980 !
990 PRINT PAGE
1000 PRINT LIN(10),CHR$(131);" SELECT MEASUREMENT :";CHR$(128)
1010 DISP "k1: Insertion loss        k2: Return loss       k3: Both    "
1020 F=0
1030 ON KEY #1 GOTO 1070
1040 ON KEY #2 GOTO 1090
1050 ON KEY #3 GOTO 1110
1060 GOTO 1060
1070 N=1
1080  GOTO 1120
1090  N=2
1100  GOTO 1120
1110  N=3
1120 F5=0
1130 PRINT PAGE
1140  PRINT LIN(10),CHR$(131);" DATA ENTRY: ";CHR$(128)
1150  PRINT "All frequencies are entered in GHz.Both channels of 8756 same sensi
t."
1160  DISP "START Frequency (GHz) ";
1170  INPUT A
1180  IF (A<=U) AND (A>=L) THEN GOTO 1210
1190  BEEP
1200  GOTO 1160
1210  DISP "STOP Frequency (GHz)";
1220  INPUT B
1230  IF (B<=U) AND (B>=L) THEN GOTO 1260
1240  BEEP
1250  GOTO 1210
1260  IF A<B THEN GOTO 1290
1270  BEEP
1280  GOTO 1120
1290  IF F5=1 THEN GOTO 1450
1300  IF (F5=0) AND ((A<>60) AND (A<>70) AND (A<>80)) THEN GOTO 1330
1310  IF (F5=0) AND ((B<>70) AND (B<>80) AND (B<>90)) THEN GOTO 1330
```

```
1320  GOTO 1450
1330  PRINT PAGE
1340  PRINT LIN(10),TAB(25),CHR$(131);" >>> WARNING <<< ";CHR$(128)
1350  PRINT LIN(2);"Measurements taken with endpoints other than 60, 70, 80, or"
1360  PRINT "90 GHz may result in misleading data.  In these cases separate band
"
1370  PRINT "measurements should be made."
1380  PRINT LIN(10)
1390  DISP
1400  DISP "Do you want to continue with the present START/STOP frequencies (Y/N
)?";
1410  INPUT T$
1420  IF T$="Y" THEN GOTO 1450
1430  F5=1
1440  GOTO 1130
1450  C=100
1460  PRINT PAGE
1470  PRINT LIN(16);"SELECT LETTER CORRESPONDING TO THE DESIRED NUMBER OF DATA P
OINTS:"
1480  PRINT
1490  PRINT TAB(10);"A: 10 DATA POINTS"
1500  PRINT TAB(10);"B: 25 DATA POINTS"
1510  PRINT TAB(10);"C: 50 DATA POINTS"
1520  PRINT TAB(10);"D: 80 DATA POINTS"
1530  PRINT TAB(10);"E: 100 DATA POINTS"
1540  PRINT TAB(10);"F: 200 DATA POINTS"
1550  PRINT TAB(10);"G: 400 DATA POINTS"
1560  P=0
1570  INPUT I$
1580  IF I$="A" THEN P=40
1590  IF I$="B" THEN P=15
1600  IF I$="C" THEN P=8
1610  IF I$="D" THEN P=5
1620  IF I$="E" THEN P=4
1630  IF I$="F" THEN P=2
1640  IF I$="G" THEN P=1
1650  IF P<>0 THEN GOTO 1680
1660  BEEP
1670  GOTO 1460
1680  PRINT PAGE
1690  PRINT LIN(12),TAB(15),CHR$(131);" INITIALIZING...PLEASE WAIT ";CHR$(128)
1700  OUTPUT A0;"PT19"
1710  OUTPUT S0;"IP"
1720  OUTPUT A0;"IP"
1730  WAIT 4000
1740  OUTPUT A0;"C2"
1750  OUTPUT A0;"C0"
1760  OUTPUT A0;"RP6"
1770  RETURN
1780  !
1790  !      <RETURN LOSS CAL.>
1800  !
1810  PRINT PAGE
1820  SHORT D10(10,401)
1830  PRINT LIN(10),TAB(20),CHR$(131);" RETURN LOSS CALIBRATION ";CHR$(128)
1840  H1=1
1850  DISP "Connect the adjustable short and press CONT."
1860  BEEP
1870  PAUSE
1880  DISP " "
1890  FOR J=1 TO 10
1900  IF J=1 THEN GOTO 1950
1910  PRINT PAGE
1920  DISP "Change position of adjustable short and press CONT after BEEP."
1930  PAUSE
1940  DISP " "
```

```
1950  OUTPUT A0;"AR" !  *** SELECT A/R MEASUREMENT ***
1960  GOSUB 7310 ! *** 8350 SETUP ***
1970  GOSUB 6620 ! *** READ 8756 ***
1980  FOR X=1 TO 401 STEP P
1990  D10(J,X)=D(X)
2000  NEXT X
2010  BEEP
2020  NEXT J
2030  PRINT PAGE
2040  PRINT LIN(12),TAB(10),CHR$(131);" COMPUTING CALIBRATION AVERAGE...PLEASE W
AIT ";CHR$(128)
2050  MAT R1=(0)
2060  MAT R2=(0)
2070  ! R1(X)(Maximum calibration average)=SQR(Va/Vr)
2080  ! R2(X)(Minimum calibration average)=SQR(Va/Vr)
2090  FOR X=1 TO 401 STEP P
2100  R1(X)=D10(1,X)
2110  R2(X)=D10(1,X)
2120  NEXT X
2130  FOR X=1 TO 401 STEP P
2140  FOR J=2 TO 10
2150  IF D10(J,X)>=R1(X) THEN R1(X)=D10(J,X)
2160  IF D10(J,X)<R2(X) THEN R2(X)=D10(J,X)
2170  ! R(X)(Linear average of the max and min)
2180  R(X)=(10^(R1(X)/20)+10^(R2(X)/20))/2
2190  NEXT J
2200  NEXT X
2210  RETURN
2220  !
2230  !    <INSERTION LOSS CAL. FOR S11 AND S22>
2240  !
2250  PRINT PAGE
2260  INPUT "Will A-coupler be removed during Insertion Loss calibration or meas
urement (Y/N)",A$
2270  IF (A$="Y") OR (A$="N") THEN GOTO 2300
2280  PRINT "Select either 'Y' OR 'N'"
2290  GOTO 2260
2300  IF H=1 THEN GOTO 2520
2310  PRINT LIN(8),TAB(20),CHR$(131);" INSERTION LOSS CALIBRATION ";CHR$(128);LI
N(1)
2320  PRINT
2330  IF H1=1 THEN GOTO 2350
2340  GOSUB 1850
2350  PRINT PAGE
2360  PRINT "GAMMA-L' computation "
2370  PRINT "---------------------"
2380  PRINT "A/R, Connect the B coupler to the Test Port and press CONT."
2390  BEEP
2400  PAUSE
2410  DISP "....taking data."
2420  GOSUB 7310 ! *** SETUP 8350 ***
2430  GOSUB 6620 ! *** Read 8756 ***
2440  FOR X=1 TO 401 STEP P
2450  ! R13(X)=GAMMA-L'
2460  R13(X)=10^(D(X)/20)/R(X)
2470  NEXT X
2480  IF A$="N" THEN GOTO 3030
2490  !
2500  !   <INSERTION LOSS S11 AND S22 MEASUREMENT>
2510  !
2520  PRINT PAGE
2530  DISP
2540  M8=-9.99999999999E99
2550  M9=9.99999999999E99
2560  PRINT "S11-DUT|Max computation "
2570  PRINT "------------------------"
```

```
2580  PRINT "A/R,Connect the device under test in the forward direction "
2590  PRINT " and press CONT "
2600  BEEP
2610  PAUSE
2620  DISP "....taking data."
2630  GOSUB 7310 ! *** SETUP 8350 ***
2640  OUTPUT A0;"AR"
2650  GOSUB 6620 ! *** Read 8756 ***
2660  FOR X=1 TO 401 STEP P
2670  ! R6=(S22 of calibration data)
2680  ! R9=(Reflection coefficient)
2690  ! R7(X)=(Uncertainty of the measurement)
2700  ! R17(X)=(Max value of S11-DUT)
2710  R6=ABS(10^(R1(X)/20)-10^(R2(X)/20))/(10^(R1(X)/20)+10^(R2(X)/20))
2720  R9=10^(D(X)/20)/R(X)
2730  R7(X)=R9*R9*R6+.01
2740  R17(X)=R7(X)+R9
2750  NEXT X
2760  IF A$="N" THEN GOTO 3500
2770  PRINT PAGE
2780  DISP
2790  PRINT "S22-DUT|Max computation "
2800  PRINT "------------------------"
2810  PRINT "A/R,Connect the device under test in the reverse direction "
2820  PRINT "and press CONT"
2830  BEEP
2840  PAUSE
2850  DISP "....taking data."
2860  GOSUB 7310 ! *** SETUP 8350 ***
2870  OUTPUT A0;"AR"
2880  GOSUB 6620 ! *** READ 8756 ***
2890  FOR X=1 TO 401 STEP P
2900  ! R6=(S22 of calibration data)
2910  ! R9=(Reflection coefficient)
2920  ! R8(X)=(Uncertainty of measurements)
2930  ! R18(X)=(Max value of S22-DUT)
2940  R6=ABS(10^(R1(X)/20)-10^(R2(X)/20))/(10^(R1(X)/20)+10^(R2(X)/20))
2950  R9=10^(D(X)/20)/R(X)
2960  R8(X)=R9*R9*R6+.01
2970  R18(X)=R8(X)+R9
2980  NEXT X
2990  IF A$="N" THEN GOTO 3330
3000  !
3010  !   <INSERTION LOSS CAL. FOR S12 AND S21>
3020  !
3030  PRINT PAGE
3040  IF A$="Y" THEN GOTO 3080
3050  PRINT "GAMMA-S' computation and INSERTION LOSS CALIBRATION "
3060  PRINT "---------------------------------------------------"
3070  IF A$="N" THEN GOTO 3160
3080  PRINT "GAMMA-S' computation and INSERTION LOSS CALIBRATION "
3090  PRINT "---------------------------------------------------"
3100  PRINT "Change A/R to B/R THEN Remove A-coupler,Insert the B coupler and"
3110  IF H=1 THEN GOTO 3370
3120  PRINT "press CONT"
3130  H=1
3140  BEEP
3150  PAUSE
3160  DISP "....taking data."
3170  GOSUB 7310 ! *** SETUP 8350 ***
3180  OUTPUT A0;"BR"
3190  GOSUB 6620 ! *** READ 8756 ***
3200  FOR X=1 TO 401 STEP P
3210  ! R14(X)=(GAMMA-S'=.2 if A-coupler is removed)
3220  IF A$="Y" THEN R14(X)=.2
3230  R6=ABS(10^(R1(X)/20)-10^(R2(X)/20))/(10^(R1(X)/20)+10^(R2(X)/20))
```

```
3240  ! R14(X)=(GAMMA-S′=S22(from calibration data)+.05 if A-coupler is in)
3250  IF A$="N" THEN R14(X)=R6+.05
3260  ! R15(X)=(Insertion Loss Calibration Average)
3270  R15(X)=10^(D(X)/20)
3280  NEXT X
3290  IF A$="N" THEN GOTO 2520
3300  !
3310  !   <INSERTION LOSS S12 AND S21 MEASUREMENT>
3320  !
3330  PRINT PAGE
3340  PRINT "S12-DUT computation "
3350  PRINT "--------------------"
3360  IF A$="N" THEN GOTO 3410
3370  PRINT "Connect the device under test (in the reverse direction)"
3380  PRINT " and press CONT"
3390  BEEP
3400  PAUSE
3410  DISP "....taking data."
3420  GOSUB 7310 ! *** SETUP 8350 ***
3430  OUTPUT A0;"BR"
3440  GOSUB 6630 ! *** READ 8756 ***
3450  FOR X=1 TO 401 STEP P
3460  ! R10(X)=(S12-DUT)
3470  R10(X)=10^(D(X)/20)/R15(X)
3480  NEXT X
3490  IF A$="N" THEN GOTO 3700
3500  PRINT PAGE
3510  PRINT "S21-DUT computation "
3520  PRINT "--------------------"
3530  IF A$="N" THEN GOTO 3580
3540  PRINT "Connect the device under test (in the forward direction)"
3550  PRINT "and press CONT"
3560  BEEP
3570  PAUSE
3580  DISP "Taking data ...."
3590  M8=-9.99999999999E99
3600  M9=9.99999999999E99
3610  GOSUB 7310 ! *** SETUP 8350 ***
3620  OUTPUT A0;"BR"
3630  GOSUB 6620 ! *** READ 8756 ***
3640  FOR X=1 TO 401 STEP P
3650  ! R11(X)=(S21-DUT)
3660  R11(X)=10^(D(X)/20)/R15(X)
3670  NEXT X
3680  IF A$="N" THEN GOTO 2770
3690  !
3700  !   <INSERTION LOSS COMPUTATION>
3710  !
3720  PRINT PAGE
3730  DISP
3740  PRINT LIN(12),TAB(15),CHR$(131);" COMPUTING INSERTION LOSS ";CHR$(128)
3750  FOR X=1 TO 401 STEP P
3760  ! R12(X)=(1+(Gamma-S′)*(Gamma-L′))*(S21-DUT)
3770  R12(X)=(1+R14(X)*R13(X))*ABS(R11(X))
3780  ! R9=(1-(Gamma-S)′*(S11-DUT))*(1-(Gamma-L′)*(S22-DUT))-(S12-DUT)*(S21-DUT)
*(Gamma-S′)*(Gamma-L′)
3790  R9=(1-R17(X)*R14(X))*(1-R18(X)*R13(X))-R10(X)*R11(X)*R13(X)*R14(X)
3800  ! R12(X)=(Maximum value of INSERTION LOSS)
3810  R12(X)=20*LGT(R12(X)/ABS(R9))
3820  ! R16(X)=(1-(Gamma-S′)*(Gamma-L′))*(S21-DUT)
3830  R16(X)=(1-R14(X)*R13(X))*ABS(R11(X))
3840  ! R9=(1+(Gamma-S′)*(S11-DUT))*(1+(Gamma-L′)*(S22-DUT)+(S12-DUT)*(S21-DUT)*
(Gamma-L′)*(Gamma-S′)
3850  R9=(1+R17(X)*R14(X))*(1+R18(X)*R13(X))+R10(X)*R11(X)*R13(X)*R14(X)
3860  ! R16(X)=(Minimum value of INSERTION LOSS)
3870  ! R11(X)=(INSERION LOSS)
```

```
3880  R16(X)=20*LGT(R16(X)/ABS(R9))
3890  R11(X)=20*LGT(R11(X))
3900  M8=MAX(M8,R12(X))
3910  M9=MIN(M9,R16(X))
3920  NEXT X
3930  RETURN
3940  !
3950  !      <DEVICE MEASUREMENT - RETURN LOSS>
3960  !
3970  PRINT PAGE
3980  PRINT LIN(8),CHR$(131);"      DEVICE MEASUREMENT     ";CHR$(128);LIN(1)
3990  PRINT " Connect the Test Device to the Test Port and press CONT."
4000  BEEP
4010  PAUSE
4020  DISP
4030  BEEP
4040  LINPUT "Enter the Device label (up to 32 characters) and press the CONTINU
E key.",N$
4050  IF N=1 THEN RETURN
4060  DISP "Taking data..."
4070  M8=-9.99999999999E99
4080  M9=9.99999999999E99
4090  GOSUB 7310 ! *** SETUP 8350 ***
4100  OUTPUT A0;"AR"
4110  GOSUB 6620 ! *** READ 8756 ***
4120  FOR X=1 TO 401 STEP P
4130  ! R19(X)=(Return loss -linear)
4140  ! R6(X)=(S22 from calibration data)
4150  R19(X)=10^(D(X)/20)/R(X)
4160  R6(X)=ABS(10^(R1(X)/20)-10^(R2(X)/20))/(10^(R1(X)/20)+10^(R2(X)/20))
4170  ! R3(X)=(Uncertainty of RETURN LOSS MEASUREMENTS)
4180  R3(X)=R19(X)*R19(X)*R6(X)+.01
4190  ! R4(X)=(Maximum value of RETURN LOSS )
4200  R4(X)=20*LGT(R19(X)+R3(X))
4210  ! R5(X)=(Minimum value of RETURN LOSS )
4220  !
4230  ! If the uncertainty exceeds measurement then default
4240  !
4250  IF R3(X)<R19(X) THEN R5(X)=20*LGT(R19(X)-R3(X))
4260  IF R3(X)>=R19(X) THEN R5(X)=20*LGT(10^(-6))
4270  R3(X)=20*LGT(R3(X))
4280  R19(X)=20*LGT(R19(X))
4290  IF R6(X)=0 THEN GOTO 4310
4300  R6(X)=20*LGT(R6(X))
4310  !
4320  M8=MAX(M8,R4(X))
4330  M9=MIN(M9,R5(X))
4340  NEXT X
4350  RETURN
4360  !
4370  !     <PLOT DATA>
4380  !
4390  N1=0
4400  IF N=1 THEN N1=1
4410  A$="N"
4420  ! SUBROUTINES FOR <PLOT DATA>
4430  GOSUB 4540 !Initialize
4440  GOSUB 4690 !Compute scale
4450  GOSUB 4830 !Label scale
4460  GOSUB 4940 !Label freq
4470  GOSUB 5080 !Label dev
4480  GOSUB 5140 !Label loss
4490  IF A$="Q" THEN RETURN
4500  GOSUB 5230 !Plot data
4510  GOTO 320 ! Return
4520  !
```

```
4530  !     Initialize
4540  PLOTTER IS 13,"GRAPHICS"
4550  GRAPHICS
4560  GCLEAR
4570  SCALE -185,1065,-1150,100
4580  PEN 1
4590  AXES 100,125,0,-1000
4600  IF A$="Q" THEN PEN 2
4610  GRID 100,125,0,-1000
4620  IF A$="Q" THEN PEN 1
4630  FRAME
4640  FRAME
4650  RETURN
4660  !
4670  !     Compute scale
4680  !
4690  FOR I=1 TO 8
4700  READ M3
4710  IF M3>=M8-M9+M3/8 THEN GOTO 4730
4720  NEXT I
4730  RESTORE 4740
4740  DATA .8,1.6,4,8,16,40,80,160
4750   M6=(M8+M9)/2
4760   M7=M6 MOD (M3/8)
4770   IF M7<=M3/16 THEN M4=M6-M7+M3/2
4780   IF M7>M3/16 THEN M4=M6-M7+M3/2+M3/8
4790  RETURN
4800  !
4810  !     Label scale
4820  !
4830  M5=M4
4840  LDIR 0
4850  FOR I=0 TO -1000 STEP -125
4860  MOVE -50,I
4870  LABEL VAL$(ABS(M5))
4880  M5=M5-M3/8
4890  NEXT I
4900  RETURN
4910  !
4920  !     Label frequency
4930  !
4940  LDIR 0
4950  MOVE -15,-1030
4960  LABEL VAL$(A)
4970  MOVE 985,-1030
4980  LABEL VAL$(B)
4990  T$=VAL$((B-A)/10)&" GHz/div"
5000  MOVE 430,-1030
5010  LABEL T$
5020  MOVE 260,-1095
5030  LABEL "Start/Stop Frequency(GHz)"
5040  RETURN
5050  !
5060  !     Label device
5070  !
5080  MOVE 390,30
5090  LABEL N$
5100  RETURN
5110  !
5120  !     Label loss
5130  !
5140  LDIR PI/2
5150  IF N1=1 THEN P$=" INSERTION LOSS(dB)"
5160  IF N1=0 THEN P$="RETURN LOSS(dB)"
5170  MOVE -100,-700
5180  LABEL P$
```

```
5190  RETURN
5200  !
5210  !     Plot data for RETURN LOSS
5220  !
5230  P1=401  ! *** NUMBER OF FREQUENCY POINTS ***
5240  IF N1=1 THEN GOTO 5570
5250  FOR X=0 TO P1-1 STEP P
5260  PLOT X*1000/(P1-1),-((M4-R19(X+1))*1000/M3)
5270  NEXT X
5280  PENUP
5290  IF A$="Q" THEN RETURN
5300  FOR X=0 TO P1-1 STEP P
5310  PLOT X*1000/(P1-1),-((M4-R4(X+1))*1000/M3)
5320  NEXT X
5330  PENUP
5340  IF A$="Q" THEN RETURN
5350  FOR X=0 TO P1-1 STEP P
5360  PLOT X*1000/(P1-1),-((M4-R5(X+1))*1000/M3)
5370  NEXT X
5380  PENUP
5390  IF A$="Q" THEN RETURN
5400  WAIT 3000
5410  PRINT PAGE
5420  A$="X"
5430  PRINT "Press P to output graph to 9845B printer,"
5440  PRINT "Press Q to output graph to 9872C plotter,"
5450  INPUT "otherwise just CONT",A$
5460  IF A$="P" THEN DUMP GRAPHICS
5470  IF A$="Q" THEN GOSUB 8960
5480  A$="X"
5490  IF N=2 THEN EXIT GRAPHICS
5500  IF N=2 THEN RETURN
5510  N1=1
5520  !
5530  ! Plot data for INSERTION LOSS
5540  !
5550  PRINT PAGE
5560  GOSUB 4410
5570  FOR X=0 TO P1-1 STEP P
5580  PLOT X*1000/(P1-1),-((M4-R11(X+1))*1000/M3)
5590  NEXT X
5600  PENUP
5610  IF A$="Q" THEN RETURN
5620  FOR X=0 TO P1-1 STEP P
5630  PLOT X*1000/(P1-1),-((M4-R12(X+1))*1000/M3)
5640  NEXT X
5650  PENUP
5660  IF A$="Q" THEN RETURN
5670  FOR X=0 TO P1-1 STEP P
5680  PLOT X*1000/(P1-1),-((M4-R16(X+1))*1000/M3)
5690  NEXT X
5700  PENUP
5710  IF A$="Q" THEN RETURN
5720  WAIT 3000
5730  PRINT PAGE
5740  A$="X"
5750  PRINT "Press P to output graph to 9845B printer,"
5760  PRINT "Press Q to output graph to 9872C plotter,"
5770  INPUT "otherwise just CONT",A$
5780  IF A$="P" THEN DUMP GRAPHICS
5790  IF A$="Q" THEN GOSUB 9130
5800  EXIT GRAPHICS
5810  RETURN
5820  !
5830  !   <DISPLAY DATA>
5840  !
```

```
5850  P1=401!  *** NUMBER OF FREQUENCY POINTS ***
5860  FOR X1=0 TO P1 STEP 11
5870  PRINT PAGE
5880  PRINT "DEVICE UNDER TEST : ",N$
5890  PRINT
5900  ON N GOSUB 6410,6450,6410
5910  FOR X2=1 TO 11*P STEP P
5920  X=X1+X2
5930  IF X>P1 THEN GOTO 5970
5940  F=(B-A)*(X-1)/(P1-1)+A
5950  ON N GOSUB 6520,6490,6520
5960  NEXT X2
5970  DISP "Press CONT..."
5980  PAUSE
5990  NEXT X1
6000  IF N<>3 THEN GOTO 320! RETURN
6010  FOR X1=0 TO P1 STEP 11
6020  PRINT PAGE
6030  PRINT "DEVICE UNDER TEST : ",N$
6040  PRINT
6050  GOSUB 6450
6060  FOR X2=1 TO 11*P STEP P
6070  X=X1+X2
6080  IF X>P1 THEN GOTO 6120
6090  F=(B-A)*(X-1)/(P1-1)+A
6100  GOSUB 6490
6110  NEXT X2
6120  DISP "Press CONT..."
6130  PAUSE
6140  NEXT X1
6150  GOTO 320 ! RETURN
6160  !
6170  !   <PRINT DATA>
6180  !
6190  P1=401 ! *** NUMBER OF FREQUENCY POINTS ***
6200  PRINTER IS 0
6210  PRINT "DEVICE UNDER TEST : ";N$
6220  PRINT
6230  ON N GOSUB 6410,6450,6410
6240  FOR X=1 TO P1 STEP P
6250  F=(B-A)*(X-1)/(P1-1)+A
6260  ON N GOSUB 6520,6490,6520
6270  NEXT X
6280  IF N<>3 THEN GOTO 6360
6290  PRINT "DEVICE UNDER TEST : ";N$
6300  PRINT
6310  GOSUB 6450
6320  FOR X=1 TO P1 STEP P
6330  F=(B-A)*(X-1)/(P1-1)+A
6340  GOSUB 6490
6350  NEXT X
6360  PRINTER IS 16
6370  GOTO 320 ! RETURN
6380  !
6390  !   Formatting
6400  !
6410  PRINT "  Frequency       Insertion     Max Ins     Min Ins     Max Unc     Min
 Unc"
6420  PRINT "    (GHz)            (dB)         (dB)        (dB)        (dB)        (d
B)"
6430  PRINT "____________________________________________________________________________
          "
______________
6440  RETURN
6450  PRINT "  Frequency       Return       Max Ret     Min Ret     Uncer        S22
"
6460  PRINT "   (GHz)          (dB)         (dB)        (dB)        (dB)         (dB
```

```
)"
6470  PRINT "____________________________________________________________________________________
"
6480  RETURN
6490  IMAGE 6X,DD.DD,5X,4D.DD,5X,4D.DD,4X,4D.DD,4X,4D.DD,4X,4D.DD
6500  PRINT USING 6490;F,R19(X),R4(X),R5(X),R3(X),R6(X)
6510  RETURN
6520  PRINT USING 6490;F,R11(X),R12(X),R16(X),R12(X)-R11(X),R16(X)-R11(X)
6530  RETURN
6540  !
6550  ! ---------------------------
6560  !     DEVICE DEPENDENT
6570  !       SUBROUTINES
6580  ! ----------------------------
6590  !
6600  !     <8756 READ ROUTINE>
6610  !
6620  SHORT D1(401),D2(401),D3(401)
6630  F1=0
6640  F2=0
6650  OUTPUT A0;"C1"
6660  OUTPUT A0;"SD5"
6670  OUTPUT A0;"RL0"
6680  IF (F1=1) OR (F2=1) THEN GOTO 6700
6690  WAIT 2000
6700  WAIT 1000
6710  OUTPUT A0;"SM"
6720  OUTPUT A0;"FD0"
6730  OUTPUT A0;"OM"
6740  IF F1=1 THEN RETURN
6750  IF F2=1 THEN RETURN
6760  ENTER A0 USING "F";D1(*)
6770  !
6780  ! *** UPPER TEST FREQUENCY REACHED? ***
6790  !
6800  IF S2=B THEN GOTO 7130
6810  !
6820  ! *** IF NOT THEN GOTO NEXT BAND ***
6830  !
6840  GOSUB 7460
6850  F1=1
6860  GOSUB 6650
6870  ENTER A0 USING "F";D2(*)
6880  F1=0
6890  !
6900  ! *** UPPER FREQUENCY REACHED? ***
6910  !
6920  IF S2=B THEN GOTO 7170
6930  !
6940  ! *** IF NOT THEN NEXT BAND ***
6950  !
6960  GOSUB 7460
6970  F2=1
6980  GOSUB 6650  .
6990  ENTER A0 USING "F";D3(*)
7000  F2=0
7010  Y=1
7020  FOR X=1 TO 401
7030  IF Y>802 THEN GOTO 7090
7040  IF Y>401 THEN GOTO 7070
7050  D(X)=D1(Y)
7060  GOTO 7100
7070  D(X)=D2(Y-401)
7080  GOTO 7100
7090  D(X)=D3(Y-802)
7100  Y=Y+3
```

```
7110  NEXT X
7120  RETURN
7130  FOR X=1 TO 401
7140  D(X)=D1(X)
7150  NEXT X
7160  RETURN
7170  Y=1
7180  FOR X=1 TO 401
7190  IF Y>401 THEN GOTO 7220
7200  D(X)=D1(Y)
7210  GOTO 7230
7220  D(X)=D2(Y-401)
7230  Y=Y+2
7240  NEXT X
7250  RETURN
7260  !
7270  !      <8350 SETUP ROUTINE>
7280  !
7290  ! ***  SET UP INITIAL FREQUENCY BAND ***
7300  !
7310  S1=A
7320  IF (A<70) AND (B>=70) THEN GOTO 7390
7330  IF (A>=70) AND (A<80) AND (B>=80) THEN GOTO 7410
7340  !
7350  !  *** SWEEP FIRST SET OF FREQUENCIES ***
7360  !
7370  S2=B
7380  GOTO 7520
7390  S2=70
7400  GOTO 7520
7410  S2=80
7420  GOTO 7520
7430  !
7440  !  *** SET UP NEXT SWEEP ***
7450  !
7460  S1=S2
7470  IF S2+10>B THEN GOTO 7370
7480  S2=S2+10
7490  !
7500  !  <SET FREQUENCY>
7510  !
7520  IMAGE "FA",DD.DDD,"GZFB",DD.DDD,"GZ"
7530  IMAGE "ST",DDDDD,"MS"
7540  OUTPUT S0;"IPMD1"
7550  OUTPUT S0 USING 7520;S1,S2
7560  OUTPUT S0 USING 7530;C
7570  RETURN
7580  !    -----------------------------------
7590  !    DISK DRIVER OR CASSETE IN THE SYSTEM
7600  !    -----------------------------------
7610  ! DISK OR CASETTE  STORAGE SUBROUTINE
7620  PRINT PAGE
7630  DISP "ENTER C FOR CASSETTE STORAGE, D FOR DISK STORAGE";
7640  INPUT B$
7650  IF (B$<>"C") AND (B$<>"D") THEN GOTO 7630
7660  IF B$="C" THEN B$=":T15"
7670  IF B$="D" THEN B$=":F"
7680  DISP "ENTER FILE NAME";
7690  INPUT F$
7700  PRINT PAGE
7710  F$=F$&B$
7720  CREATE F$,1010,120
7730  ASSIGN #1 TO F$
7740  PRINT #1;N$,A,B,P,M3,M6,M7,M8,M9
7750  FOR X=1 TO 401 STEP P
7760  F=(B-A)*(X-1)/(P1-1)+A
```

```
7770  R6(X)=ABS(10^(R1(X)/20)-10^(R2(X)/20))/(10^(R1(X)/20)+10^(R2(X)/20))
7780  IF R6(X)=0 THEN GOTO 7800
7790  R6(X)=20*LGT(R6(X))
7800  !
7810  PRINT #1;F,R(X),R4(X),R5(X),R3(X),R11(X),R12(X),R16(X),R10(X),R13(X),R14(X
),R17(X),R6(X)
7820  NEXT X
7830  GOTO 320
7840  ! DISK OR CASETTE  DATA RETRIVAL SUBROUTINE
7850  PRINT PAGE
7860  DISP "ENTER C FOR CASSETTE READ , D FOR DISK READ";
7870  INPUT B$
7880  IF (B$<>"C") AND (B$<>"D") THEN GOTO 7860
7890  IF B$="D" THEN B$=":F"
7900  IF B$="C" THEN B$=":T15"
7910  DISP "ENTER FILE NAME ";
7920  INPUT F$
7930  F$=F$&B$
7940  ASSIGN #1 TO F$
7950  READ #1;N$,A,B,P,M3,M6,M7,M8,M9
7960  FOR X=1 TO 401 STEP P
7970  READ #1;F,R(X),R4(X),R5(X),R3(X),R11(X),R12(X),R16(X),R10(X),R13(X),R14(X)
,R17(X),R6(X)
7980  NEXT X
7990  GOTO 320
8000  !    ----------------------------------------
8010  !    DISPLAY or PRINT the INTERMEDIATE VALUES
8020  !    ----------------------------------------
8030  !    <Intermediate values for INSERTION>
8040  PRINT PAGE
8050  A$="X"
8060  INPUT "Do you want results printed ? (enter 'Y' for printout)",A$
8070  IF A$="Y" THEN GOTO 8360
8080  !
8090  !    PRINT TO DISPLAY
8100  !
8110  FOR Y=0 TO P1-1 STEP 11*P
8120  PRINT PAGE
8130  PRINT "DEVICE UNDER TEST : ",N$
8140  PRINT
8150  PRINT
8160  PRINT
8170  PRINT "   F        S21       S12       S11       S22    GAMMA-S'  GAMMA-L'
 Avg "
8180  PRINT "______________________________________________________________________
________"
8190  PRINT
8200  FOR W=1 TO 11*P STEP P
8210  X=Y+W
8220  IF X>P1 THEN GOTO 8270
8230  F=(B-A)*(X-1)/(P1-1)+A
8240  Z=10^(R11(X)/20)
8250  PRINT USING 8310;F,Z,R10(X),R17(X),R6(X),R14(X),R13(X),R15(X)
8260  NEXT W
8270  DISP "Press  CONT . . . "
8280  PAUSE
8290  DISP
8300  NEXT Y
8310  IMAGE X,DD.DD,4X,DD.DD,4X,DD.DD,4X,DD.DD,4X,DD.DD,5X,DD.DD,5X,DD.DD,5X,DD.
DD
8320  GOTO 320
8330  !
8340  !     PRINT TO PRINTER
8350  !
8360  PRINTER IS 0
8370  PRINT
```

```
8380  PRINT "Device under test : ";N$
8390  PRINT
8400  PRINT
8410  PRINT "   F         S21       S12       S11       S22      GAMMA-S'  GAMMA-L'
 Avg "
8420  PRINT "__________________________________________________________________________
__________"
8430  FOR X=1 TO P1 STEP P
8440  F=(B-A)*(X-1)/(P1-1)+A
8450  Z=10^(R11(X)/20)
8460  PRINT USING 8310;F,Z,R10(X),R17(X),R6(X),R14(X),R13(X),R15(X)
8470  NEXT X
8480  PRINTER IS 16
8490  GOTO 320
8500  !   <Intermediate values for RETURN>
8510  PRINT PAGE
8520  A$="X"
8530  INPUT "Do you want results printed ?(enter 'Y'for printout)",A$
8540  IF A$="Y" THEN GOTO 8790
8550  FOR Y=0 TO P1-1 STEP 11*P
8560  PRINT PAGE
8570  PRINT "DEVICE UNDER TEST :",N$
8580  PRINT
8590  PRINT
8600  PRINT
8610  PRINT "  F        R1(X)     R2(X)      R(X)       R6(X)     "
8620  PRINT "--------------------------------------------"
8630  PRINT
8640  FOR W=1 TO 11*P STEP P
8650  X=Y+W
8660  IF X>P1 THEN GOTO 8740
8670  F=(B-A)*(X-1)/(P1-1)+A
8680  K=10^(R1(X)/20)
8690  L=10^(R2(X)/20)
8700  R(X)=(K+L)/2
8710  R6(X)=(K-L)/(K+L)
8720  PRINT USING 8770;F,K,L,R(X),R6(X)
8730  NEXT W
8740  DISP "Press CONT . . . . . "
8750  PAUSE
8760  NEXT Y
8770  IMAGE X,DD.DD,4X,DD.DD,4X,DD.DD,4X,DD.DD,4X,DD.DD
8780  GOTO 320
8790  PRINTER IS 0
8800  PRINT
8810  PRINT "Device under test  : ";N$
8820  PRINT
8830  PRINT
8840  PRINT "  F        R1(X)     R2(X)      R(X)      R6(X)   "
8850  PRINT "---------------------------------------------"
8860  FOR X=1 TO P1 STEP P
8870  F=(B-A)*(X-1)/(P1-1)+A
8880  K=10^(R1(X)/20)
8890  L=10^(R2(X)/20)
8900  R(X)=(K+L)/2
8910  R6(X)=(K-L)/(K+L)
8920  PRINT USING 8770;F,K,L,R(X),R6(X)
8930  NEXT X
8940  PRINTER IS 16
8950  GOTO 320
8960  !
8970  ! *** PLOT RETURN LOSS ON 9872C PLOTTER ***
8980  !
8990  PLOTTER IS 7,5,"9872A"
9000  LIMIT 37,240,57,171
9010  GOSUB 4560
```

```
9020  GOSUB 4440
9030  GOSUB 5230
9040  PEN 3
9050  GOSUB 5300
9060  GOSUB 5350
9070  PEN 0
9080  EXIT GRAPHICS
9090  RETURN
9100  !
9110  ! *** PLOT INSERTION LOSS ON 9872C ***
9120  !
9130  PLOTTER IS 7,5,"9872A"
9140  LIMIT 37,240,57,171
9150  GOSUB 4560
9160  GOSUB 4440
9170  GOSUB 5570
9180  PEN 3
9190  GOSUB 5620
9200  GOSUB 5670
9210  PEN 0
9220  EXIT GRAPHICS
9230  RETURN
9240  END
```

APPENDIX C

TABULAR DATA OF MEASUREMENTS USING SCHOTTKY BARRIER DIODE DETECTOR

Tabular data for the calibration and system accuracy of the Automated Millimeter-Wave Scalar Network Analyzer using the Schottky Barrier Diode Detector are contained in this Appendix. An explaination of this data can be found in Chapter III.

TABLE II

PRINTED OUTPUT OF FIXED SHORT RETURN LOSS USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : FIXED SHORT

Frequency (GHz)	Return (dB)	Max Ret (dB)	Min Ret (dB)	Uncer (dB)	S22 (dB)
60.00	-.31	.69	-1.44	-18.55	-18.70
60.15	-.74	.34	-1.98	-18.31	-17.57
60.30	1.18	2.67	-.61	-13.40	-16.18
60.45	-.41	.66	-1.62	-18.11	-18.03
60.60	-.94	-.10	-1.87	-20.84	-19.98
60.75	1.02	2.39	-.60	-14.35	-16.86
60.90	.04	1.45	-1.64	-15.04	-15.63
61.05	-1.54	-.40	-2.84	-18.65	-16.35
61.20	-.79	.32	-2.07	-18.07	-17.20
61.35	1.12	2.49	-.52	-14.21	-16.90
61.50	-.56	.71	-2.04	-16.65	-16.14
61.65	-1.43	-.31	-2.72	-18.67	-16.59
61.80	.51	1.71	-.89	-16.04	-17.62
61.95	-.07	.93	-1.20	-18.34	-18.96
62.10	-1.13	-.18	-2.20	-19.87	-18.51
62.25	.16	1.37	-1.25	-16.34	-17.25
62.40	.57	1.53	-.52	-18.04	-19.90
62.55	-.92	-.09	-1.85	-20.82	-19.98
62.70	-.12	.92	-1.29	-18.07	-18.56
62.85	.70	1.65	-.37	-18.02	-20.14
63.00	-.66	.05	-1.43	-22.06	-21.92
63.15	.42	1.38	-.66	-18.26	-19.84
63.30	.20	.93	-.60	-20.91	-22.34
63.45	-.20	.24	-.67	-25.80	-27.28
63.60	.55	1.19	-.13	-21.91	-24.17
63.75	.35	1.07	-.44	-20.88	-22.59
63.90	-.42	.18	-1.06	-23.32	-23.86
64.05	-.15	.20	-.51	-27.92	-30.10
64.20	.15	.44	-.14	-29.39	-32.74
64.35	-.02	.39	-.44	-26.42	-28.42
64.50	-.35	.17	-.89	-24.67	-25.61
64.65	-.17	.27	-.63	-25.89	-27.46
64.80	.16	.41	-.10	-30.36	-34.14
64.95	-.06	.25	-.37	-29.05	-31.83
65.10	-.31	.15	-.79	-25.61	-26.84
65.25	-.04	.36	-.46	-26.51	-28.49
65.40	.20	.52	-.13	-28.29	-31.30
65.55	-.02	.23	-.29	-30.60	-34.14
65.70	-.30	.13	-.75	-26.21	-27.60
65.85	.05	.58	-.51	-23.96	-25.56
66.00	.44	1.10	-.27	-21.58	-23.57
66.15	.12	.68	-.47	-23.45	-25.10
66.30	-.33	.05	-.72	-27.37	-29.02
66.45	.11	.60	-.40	-24.69	-26.55
66.60	.37	.97	-.27	-22.57	-24.57
66.75	-.31	.29	-.95	-23.28	-24.04
66.90	-.06	.37	-.52	-25.88	-27.67
67.05	.34	1.05	-.43	-21.02	-22.74
67.20	-.90	-.14	-1.73	-21.70	-21.02
67.35	.01	.78	-.84	-20.59	-21.59
67.50	-1.34	-.27	-2.56	-18.96	-17.09
67.65	-.43	.55	-1.54	-18.88	-18.82
67.80	.55	1.56	-.58	-17.68	-19.48
67.95	.63	1.51	-.35	-18.79	-20.84
68.10	-.61	.25	-1.56	-20.26	-19.98
68.25	-1.14	-.15	-2.26	-19.47	-18.05
68.40	-.69	.15	-1.62	-20.56	-20.17
68.55	.33	1.32	-.79	-18.05	-19.43
68.70	.54	1.27	-.26	-20.60	-22.67
68.85	-.34	.32	-1.06	-22.35	-22.89
69.00	-.74	-.01	-1.53	-21.88	-21.56

TABLE II (cont.)

69.15	.20	1.12	-.83	-18.85	-20.04
69.30	.69	1.59	-.31	-18.60	-20.75
69.45	-.72	.10	-1.63	-20.78	-20.34
69.60	-.78	.18	-1.86	-19.42	-18.72
69.75	.79	2.08	-.72	-15.11	-17.20
69.90	.63	1.94	-.91	-15.16	-16.94
70.05	-.24	.65	-1.24	-19.57	-19.96
70.20	.99	2.05	-.21	-16.79	-19.40
70.35	-.38	.62	-1.52	-18.60	-18.61
70.50	-1.04	-.14	-2.03	-20.35	-19.22
70.65	.27	1.18	-.75	-18.87	-20.20
70.80	.40	1.29	-.59	-18.94	-20.54
70.95	-.82	-.04	-1.69	-21.32	-20.75
71.10	-.30	.46	-1.13	-21.10	-21.55
71.25	.58	1.27	-.17	-21.12	-23.33
71.40	-.22	.54	-1.05	-20.99	-21.59
71.55	-.64	.01	-1.34	-22.85	-22.86
71.70	.01	.61	-.63	-22.93	-24.26
71.85	-.02	.47	-.53	-24.81	-26.43
72.00	-.56	.03	-1.18	-23.74	-24.08
72.15	.11	.93	-.79	-19.97	-21.11
72.30	.56	1.25	-.20	-21.02	-23.16
72.45	-.32	.17	-.84	-25.12	-26.21
72.60	-.23	.22	-.71	-25.69	-27.08
72.75	.32	.82	-.21	-24.23	-26.42
72.90	.25	.74	-.28	-24.36	-26.42
73.05	-.16	.10	-.43	-30.51	-33.74
73.20	.05	.27	-.18	-31.70	-36.01
73.35	.17	.55	-.22	-26.89	-29.41
73.50	.07	.49	-.38	-26.00	-28.06
73.65	-.23	.14	-.61	-27.51	-29.41
73.80	-.20	.12	-.54	-28.53	-30.82
73.95	-.28	.05	-.62	-28.58	-30.73
74.10	.12	.44	-.21	-28.34	-31.21
74.25	.39	.94	-.20	-23.26	-25.40
74.40	-.11	.58	-.85	-21.85	-22.78
74.55	-.60	.11	-1.37	-21.99	-21.96
74.70	-.54	.18	-1.33	-21.83	-21.89
74.85	.34	.87	-.23	-23.60	-25.71
75.00	-.05	.77	-.96	-20.08	-20.90
75.15	-.96	.01	-2.05	-19.54	-18.49
75.30	-.02	.71	-.83	-21.10	-22.09
75.45	-.10	.42	-.65	-24.26	-25.61
75.60	-.59	.24	-1.52	-20.50	-20.29
75.75	.59	1.39	-.29	-19.75	-21.82
75.90	-.18	.57	-1.01	-21.05	-21.72
76.05	-.75	.12	-1.70	-20.38	-19.85
76.20	.83	1.90	-.40	-16.76	-19.03
76.35	-.55	.50	-1.74	-18.39	-18.05
76.50	-1.03	-.12	-2.06	-20.10	-18.96
76.65	.66	1.76	-.61	-16.70	-18.63
76.80	-1.29	-.18	-2.56	-18.61	-16.81
76.95	-1.01	.07	-2.25	-18.55	-17.29
77.10	.02	.78	-.80	-20.83	-21.89
77.25	.74	1.74	-.40	-17.49	-19.64
77.40	.16	1.15	-.96	-18.19	-19.25
77.55	-.38	.40	-1.22	-21.02	-21.30
77.70	-1.31	-.16	-2.64	-18.28	-16.41
77.85	-1.56	-.32	-3.01	-17.84	-15.42
78.00	-1.32	-.10	-2.73	-17.77	-15.84
78.15	-.82	.25	-2.05	-18.44	-17.55
78.30	-.15	.62	-1.00	-20.78	-21.49
78.45	.65	1.55	-.36	-18.54	-20.60
78.60	.30	1.04	-.52	-20.65	-22.23
78.75	-1.22	-.18	-2.41	-19.11	-17.48
78.90	-.55	.44	-1.66	-18.95	-18.65

TABLE II (cont.)

79.05	.51	1.32	-.38	-19.71	-21.62
79.20	-1.42	-.29	-2.72	-18.56	-16.49
79.35	.32	1.39	-.91	-17.27	-18.56
79.50	.62	1.38	-.22	-20.13	-22.30
79.65	-.45	.20	-1.15	-22.64	-23.01
79.80	-.63	.31	-1.69	-19.45	-19.03
79.95	.35	1.42	-.87	-17.29	-18.65
80.10	-.74	.34	-1.98	-18.31	-17.57
80.25	-.94	-.10	-1.87	-20.84	-19.98
80.40	-1.54	-.40	-2.84	-18.65	-16.35
80.55	-.56	.71	-2.04	-16.65	-16.14
80.70	-.07	.93	-1.20	-18.34	-18.96
80.85	.57	1.53	-.52	-18.04	-19.90
81.00	.70	1.65	-.37	-18.02	-20.14
81.15	.20	.93	-.60	-20.91	-22.34
81.30	.35	1.07	-.44	-20.88	-22.59
81.45	.15	.44	-.14	-29.39	-32.74
81.60	-.17	.27	-.63	-25.89	-27.46
81.75	-.31	.15	-.79	-25.61	-26.84
81.90	-.02	.23	-.29	-30.60	-34.14
82.05	.44	1.10	-.27	-21.58	-23.57
82.20	.11	.60	-.40	-24.69	-26.55
82.35	-.06	.37	-.52	-25.88	-27.67
82.50	.01	.78	-.84	-20.59	-21.59
82.65	.55	1.56	-.58	-17.68	-19.48
82.80	-1.14	-.15	-2.26	-19.47	-18.05
82.95	.54	1.27	-.26	-20.60	-22.67
83.10	.20	1.12	-.83	-18.85	-20.04
83.25	-.78	.18	-1.86	-19.42	-18.72
83.40	-.24	.65	-1.24	-19.57	-19.96
83.55	-1.04	-.14	-2.03	-20.35	-19.22
83.70	-.82	-.04	-1.69	-21.32	-20.75
83.85	-.22	.54	-1.05	-20.99	-21.59
84.00	-.02	.47	-.53	-24.81	-26.43
84.15	.56	1.25	-.20	-21.02	-23.16
84.30	.32	.82	-.21	-24.23	-26.42
84.45	.05	.27	-.18	-31.70	-36.01
84.60	-.23	.14	-.61	-27.51	-29.41
84.75	.12	.44	-.21	-28.34	-31.21
84.90	-.60	.11	-1.37	-21.99	-21.96
85.05	-.05	.77	-.96	-20.08	-20.90
85.20	-.10	.42	-.65	-24.26	-25.61
85.35	-.18	.57	-1.01	-21.05	-21.72
85.50	-.55	.50	-1.74	-18.39	-18.05
85.65	-1.29	-.18	-2.56	-18.61	-16.81
85.80	.74	1.74	-.40	-17.49	-19.64
85.95	-1.31	-.16	-2.64	-18.28	-16.41
86.10	-.82	.25	-2.05	-18.44	-17.55
86.25	.30	1.04	-.52	-20.65	-22.23
86.40	.51	1.32	-.38	-19.71	-21.62
86.55	.62	1.38	-.22	-20.13	-22.30
86.70	.35	1.42	-.87	-17.29	-18.65
86.85	-1.54	-.40	-2.84	-18.65	-16.35
87.00	.57	1.53	-.52	-18.04	-19.90
87.15	.35	1.07	-.44	-20.88	-22.59
87.30	-.31	.15	-.79	-25.61	-26.84
87.45	.11	.60	-.40	-24.69	-26.55
87.60	.55	1.56	-.58	-17.68	-19.48
87.75	.20	1.12	-.83	-18.85	-20.04
87.90	-1.04	-.14	-2.03	-20.35	-19.22
88.05	-.02	.47	-.53	-24.81	-26.43
88.20	.05	.27	-.18	-31.70	-36.01
88.35	-.60	.11	-1.37	-21.99	-21.96
88.50	-.18	.57	-1.01	-21.05	-21.72
88.65	.74	1.74	-.40	-17.49	-19.64
88.80	.30	1.04	-.52	-20.65	-22.23

TABLE II (cont.)

88.95	.35	1.42	-.87	-17.29	-18.65
89.10	.35	1.07	-.44	-20.88	-22.59
89.25	.55	1.56	-.58	-17.68	-19.48
89.40	-.02	.47	-.53	-24.81	-26.43
89.55	-.18	.57	-1.01	-21.05	-21.72
89.70	.35	1.42	-.87	-17.29	-18.65
89.85	-.02	.47	-.53	-24.81	-26.43
90.00	-.02	.47	-.53	-24.81	-26.43

TABLE III

PRINTED OUTPUT OF MATCHED LOAD RETURN LOSS USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : MATCHED LOAD

Frequency (GHz)	Return (dB)	Max Ret (dB)	Min Ret (dB)	Uncer (dB)	S22 (dB)
60.00	-25.13	-23.64	-26.93	-39.70	-18.70
60.15	-25.22	-23.71	-27.05	-39.66	-17.57
60.30	-25.91	-24.29	-27.91	-39.66	-16.18
60.45	-27.95	-25.98	-30.51	-39.83	-18.03
60.60	-30.79	-28.19	-34.52	-39.93	-19.98
60.75	-31.62	-28.80	-35.85	-39.91	-16.86
60.90	-33.02	-29.78	-38.24	-39.93	-15.63
61.05	-30.63	-28.06	-34.30	-39.89	-16.35
61.20	-31.15	-28.45	-35.09	-39.91	-17.20
61.35	-29.78	-27.41	-33.04	-39.87	-16.90
61.50	-32.38	-29.33	-37.10	-39.92	-16.14
61.65	-31.44	-28.66	-35.55	-39.91	-16.59
61.80	-33.32	-29.99	-38.77	-39.95	-17.62
61.95	-34.07	-30.50	-40.21	-39.96	-18.96
62.10	-30.88	-28.25	-34.67	-39.92	-18.51
62.25	-31.30	-28.56	-35.33	-39.91	-17.25
62.40	-31.22	-28.50	-35.18	-39.93	-19.90
62.55	-31.05	-28.38	-34.93	-39.93	-19.98
62.70	-31.72	-28.87	-36.00	-39.93	-18.56
62.85	-33.30	-29.99	-38.73	-39.96	-20.14
63.00	-34.19	-30.59	-40.46	-39.97	-21.92
63.15	-34.34	-30.69	-40.78	-39.97	-19.84
63.30	-29.25	-27.02	-32.26	-39.92	-22.34
63.45	-27.81	-25.89	-30.28	-39.94	-27.28
63.60	-26.55	-24.85	-28.66	-39.88	-24.17
63.75	-26.74	-25.01	-28.91	-39.86	-22.59
63.90	-27.32	-25.48	-29.64	-39.90	-23.86
64.05	-27.69	-25.80	-30.12	-39.95	-30.10
64.20	-28.86	-26.73	-31.69	-39.97	-32.74
64.35	-29.88	-27.51	-33.14	-39.97	-28.42
64.50	-30.51	-27.99	-34.08	-39.96	-25.61
64.65	-32.53	-29.46	-37.33	-39.98	-27.46
64.80	-33.79	-30.33	-39.63	-39.99	-34.14
64.95	-38.36	-33.12	-53.66	-40.00	-31.83
65.10	-35.13	-31.20	-42.49	-39.99	-26.84
65.25	-36.02	-31.76	-44.72	-39.99	-28.49
65.40	-35.11	-31.19	-42.44	-39.99	-31.30
65.55	-33.77	-30.31	-39.59	-39.99	-34.14
65.70	-34.84	-31.02	-41.83	-39.99	-27.60
65.85	-36.91	-32.30	-47.42	-39.99	-25.56
66.00	-40.25	-34.10	-120.00	-39.99	-23.57
66.15	-41.02	-34.47	-120.00	-40.00	-25.10
66.30	-39.84	-33.90	-74.68	-40.00	-29.02
66.45	-36.84	-32.26	-47.19	-39.99	-26.55
66.60	-40.34	-34.14	-120.00	-40.00	-24.57
66.75	-36.65	-32.14	-46.57	-39.99	-24.04
66.90	-41.34	-34.62	-120.00	-40.00	-27.67
67.05	-34.28	-30.65	-40.64	-39.98	-22.74
67.20	-34.16	-30.57	-40.39	-39.97	-21.02
67.35	-32.23	-29.24	-36.83	-39.96	-21.59
67.50	-32.52	-29.44	-37.34	-39.93	-17.09
67.65	-31.64	-28.81	-35.86	-39.93	-18.82
67.80	-31.70	-28.86	-35.95	-39.94	-19.48
67.95	-31.28	-28.55	-35.27	-39.94	-20.84
68.10	-31.02	-28.36	-34.87	-39.93	-19.98
68.25	-31.49	-28.70	-35.63	-39.92	-18.05
68.40	-32.52	-29.44	-37.32	-39.95	-20.17
68.55	-32.68	-29.55	-37.60	-39.95	-19.43
68.70	-34.04	-30.49	-40.14	-39.97	-22.67
68.85	-37.98	-32.91	-51.67	-39.99	-22.89
69.00	-36.49	-32.04	-46.09	-39.98	-21.56

TABLE III (cont.)

69.15	-33.17	-29.90	-38.49	-39.96	-20.04
69.30	-31.53	-28.74	-35.68	-39.94	-20.75
69.45	-30.45	-27.93	-34.00	-39.93	-20.34
69.60	-29.75	-27.40	-32.99	-39.89	-18.72
69.75	-28.83	-26.67	-31.70	-39.84	-17.20
69.90	-29.71	-27.36	-32.93	-39.87	-16.94
70.05	-29.11	-26.91	-32.07	-39.89	-19.96
70.20	-32.20	-29.22	-36.79	-39.94	-19.40
70.35	-34.76	-30.96	-41.68	-39.97	-18.61
70.50	-38.66	-33.28	-55.65	-39.99	-19.22
70.65	-39.44	-33.69	-63.60	-39.99	-20.20
70.80	-35.79	-31.61	-44.13	-39.98	-20.54
70.95	-33.54	-30.15	-39.17	-39.96	-20.75
71.10	-31.87	-28.98	-36.22	-39.95	-21.55
71.25	-32.33	-29.32	-36.99	-39.97	-23.33
71.40	-32.96	-29.76	-38.10	-39.96	-21.59
71.55	-36.98	-32.33	-47.66	-39.99	-22.86
71.70	-39.42	-33.68	-63.30	-39.99	-24.26
71.85	-35.12	-31.20	-42.47	-39.99	-26.43
72.00	-30.20	-27.75	-33.63	-39.95	-24.08
72.15	-28.90	-26.74	-31.77	-39.90	-21.11
72.30	-28.44	-26.39	-31.14	-39.91	-23.16
72.45	-28.90	-26.75	-31.75	-39.95	-26.21
72.60	-29.54	-27.25	-32.66	-39.96	-27.08
72.75	-31.12	-28.44	-35.01	-39.97	-26.42
72.90	-31.98	-29.07	-36.40	-39.97	-26.42
73.05	-32.49	-29.43	-37.24	-39.99	-33.74
73.20	-31.04	-28.39	-34.88	-39.99	-36.01
73.35	-31.11	-28.44	-34.99	-39.98	-29.41
73.50	-32.25	-29.26	-36.84	-39.98	-28.06
73.65	-32.84	-29.67	-37.86	-39.98	-29.41
73.80	-33.03	-29.81	-38.21	-39.99	-30.82
73.95	-36.10	-31.81	-44.93	-39.99	-30.73
74.10	-38.11	-32.98	-52.29	-40.00	-31.21
74.25	-38.57	-33.23	-54.95	-39.99	-25.40
74.40	-38.94	-33.43	-57.83	-39.99	-22.78
74.55	-34.69	-30.92	-41.51	-39.98	-21.96
74.70	-34.61	-30.87	-41.34	-39.98	-21.89
74.85	-32.08	-29.14	-36.57	-39.97	-25.71
75.00	-31.25	-28.53	-35.23	-39.94	-20.90
75.15	-29.95	-27.55	-33.28	-39.90	-18.49
75.30	-31.64	-28.82	-35.85	-39.95	-22.09
75.45	-33.66	-30.24	-39.40	-39.98	-25.61
75.60	-41.22	-34.56	-120.00	-39.99	-20.29
75.75	-41.19	-34.55	-120.00	-39.99	-21.82
75.90	-41.39	-34.65	-120.00	-39.99	-21.72
76.05	-42.80	-35.26	-120.00	-40.00	-19.85
76.20	-40.70	-34.32	-120.00	-39.99	-19.03
76.35	-38.74	-33.32	-56.20	-39.99	-18.05
76.50	-35.89	-31.67	-44.40	-39.97	-18.96
76.65	-32.42	-29.37	-37.15	-39.94	-18.63
76.80	-32.47	-29.40	-37.26	-39.93	-16.81
76.95	-32.80	-29.64	-37.84	-39.94	-17.29
77.10	-32.53	-29.45	-37.34	-39.96	-21.89
77.25	-32.71	-29.58	-37.67	-39.95	-19.64
77.40	-32.13	-29.17	-36.67	-39.94	-19.25
77.55	-32.07	-29.13	-36.56	-39.95	-21.30
77.70	-32.06	-29.11	-36.56	-39.92	-16.41
77.85	-32.17	-29.18	-36.75	-39.91	-15.42
78.00	-32.17	-29.19	-36.75	-39.92	-15.84
78.15	-31.69	-28.84	-35.94	-39.92	-17.55
78.30	-32.21	-29.23	-36.79	-39.96	-21.49
78.45	-31.41	-28.65	-35.49	-39.94	-20.60
78.60	-32.37	-29.34	-37.07	-39.96	-22.23
78.75	-32.83	-29.65	-37.88	-39.94	-17.48
78.90	-33.52	-30.14	-39.15	-39.96	-18.65

TABLE III (cont.)

79.05	-36.98	-32.33	-47.64	-39.99	-21.62
79.20	-36.21	-31.87	-45.31	-39.97	-16.49
79.35	-36.56	-32.08	-46.32	-39.98	-18.56
79.50	-36.17	-31.85	-45.15	-39.98	-22.30
79.65	-34.14	-30.56	-40.35	-39.98	-23.01
79.80	-32.87	-29.69	-37.95	-39.95	-19.03
79.95	-32.54	-29.46	-37.37	-39.94	-18.65
80.10	-25.22	-23.71	-27.05	-39.66	-17.57
80.25	-30.79	-28.19	-34.52	-39.93	-19.98
80.40	-30.63	-28.06	-34.30	-39.89	-16.35
80.55	-32.38	-29.33	-37.10	-39.92	-16.14
80.70	-34.07	-30.50	-40.21	-39.96	-18.96
80.85	-31.22	-28.50	-35.18	-39.93	-19.90
81.00	-33.30	-29.99	-38.73	-39.96	-20.14
81.15	-29.25	-27.02	-32.26	-39.92	-22.34
81.30	-26.74	-25.01	-28.91	-39.86	-22.59
81.45	-28.86	-26.73	-31.69	-39.97	-32.74
81.60	-32.53	-29.46	-37.33	-39.98	-27.46
81.75	-35.13	-31.20	-42.49	-39.99	-26.84
81.90	-33.77	-30.31	-39.59	-39.99	-34.14
82.05	-40.25	-34.10	-120.00	-39.99	-23.57
82.20	-36.84	-32.26	-47.19	-39.99	-26.55
82.35	-41.34	-34.62	-120.00	-40.00	-27.67
82.50	-32.23	-29.24	-36.83	-39.96	-21.59
82.65	-31.70	-28.86	-35.95	-39.94	-19.48
82.80	-31.49	-28.70	-35.63	-39.92	-18.05
82.95	-34.04	-30.49	-40.14	-39.97	-22.67
83.10	-33.17	-29.90	-38.49	-39.96	-20.04
83.25	-29.75	-27.40	-32.99	-39.89	-18.72
83.40	-29.11	-26.91	-32.07	-39.89	-19.96
83.55	-38.66	-33.28	-55.65	-39.99	-19.22
83.70	-33.54	-30.15	-39.17	-39.96	-20.75
83.85	-32.96	-29.76	-38.10	-39.96	-21.59
84.00	-35.12	-31.20	-42.47	-39.99	-26.43
84.15	-28.44	-26.39	-31.14	-39.91	-23.16
84.30	-31.12	-28.44	-35.01	-39.97	-26.42
84.45	-31.04	-28.39	-34.88	-39.99	-36.01
84.60	-32.84	-29.67	-37.86	-39.98	-29.41
84.75	-38.11	-32.98	-52.29	-40.00	-31.21
84.90	-34.69	-30.92	-41.51	-39.98	-21.96
85.05	-31.25	-28.53	-35.23	-39.94	-20.90
85.20	-33.66	-30.24	-39.40	-39.98	-25.61
85.35	-41.39	-34.65	-120.00	-39.99	-21.72
85.50	-38.74	-33.32	-56.20	-39.99	-18.05
85.65	-32.47	-29.40	-37.26	-39.93	-16.81
85.80	-32.71	-29.58	-37.67	-39.95	-19.64
85.95	-32.06	-29.11	-36.56	-39.92	-16.41
86.10	-31.69	-28.84	-35.94	-39.92	-17.55
86.25	-32.37	-29.34	-37.07	-39.96	-22.23
86.40	-36.98	-32.33	-47.64	-39.99	-21.62
86.55	-36.17	-31.85	-45.15	-39.98	-22.30
86.70	-32.54	-29.46	-37.37	-39.94	-18.65
86.85	-30.63	-28.06	-34.30	-39.89	-16.35
87.00	-31.22	-28.50	-35.18	-39.93	-19.90
87.15	-26.74	-25.01	-28.91	-39.86	-22.59
87.30	-35.13	-31.20	-42.49	-39.99	-26.84
87.45	-36.84	-32.26	-47.19	-39.99	-26.55
87.60	-31.70	-28.86	-35.95	-39.94	-19.48
87.75	-33.17	-29.90	-38.49	-39.96	-20.04
87.90	-38.66	-33.28	-55.65	-39.99	-19.22
88.05	-35.12	-31.20	-42.47	-39.99	-26.43
88.20	-31.04	-28.39	-34.88	-39.99	-36.01
88.35	-34.69	-30.92	-41.51	-39.98	-21.96
88.50	-41.39	-34.65	-120.00	-39.99	-21.72
88.65	-32.71	-29.58	-37.67	-39.95	-19.64
88.80	-32.37	-29.34	-37.07	-39.96	-22.23

TABLE III (cont.)

88.95	-32.54	-29.46	-37.37	-39.94	-18.65
89.10	-26.74	-25.01	-28.91	-39.86	-22.59
89.25	-31.70	-28.86	-35.95	-39.94	-19.48
89.40	-35.12	-31.20	-42.47	-39.99	-26.43
89.55	-41.39	-34.65	-120.00	-39.99	-21.72
89.70	-32.54	-29.46	-37.37	-39.94	-18.65
89.85	-35.12	-31.20	-42.47	-39.99	-26.43
90.00	-35.12	-31.20	42.47	-39.99	-26.43

TABLE IV

PRINTED OUTPUT OF RETURN LOSS FOR 5 dB ATTENUATOR WITH SHORTED OUTPUT USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 5 dB ATTENUATOR WITH SHORT

Frequency (GHz)	Return (dB)	Max Ret (dB)	Min Ret (dB)	Uncer (dB)	S22 (dB)
60.00	-10.86	-10.28	-11.47	-34.18	-18.70
60.15	-12.61	-11.99	-13.27	-35.26	-17.57
60.30	-10.32	-9.65	-11.05	-32.24	-16.18
60.45	-10.64	-10.04	-11.27	-33.62	-18.03
60.60	-10.50	-9.96	-11.07	-34.45	-19.98
60.75	-11.38	-10.74	-12.06	-33.79	-16.86
60.90	-10.83	-10.14	-11.58	-32.52	-15.63
61.05	-10.71	-10.05	-11.42	-32.80	-16.35
61.20	-10.72	-10.09	-11.39	-33.27	-17.20
61.35	-10.83	-10.19	-11.51	-33.23	-16.90
61.50	-12.49	-11.83	-13.21	-34.52	-16.14
61.65	-10.72	-10.07	-11.42	-32.94	-16.59
61.80	-10.58	-9.97	-11.23	-33.35	-17.62
61.95	-10.28	-9.71	-10.88	-33.73	-18.96
62.10	-10.93	-10.35	-11.55	-34.16	-18.51
62.25	-9.87	-9.24	-10.55	-32.34	-17.25
62.40	-10.42	-9.89	-11.00	-34.35	-19.90
62.55	-11.48	-10.94	-12.06	-35.33	-19.98
62.70	-12.31	-11.72	-12.94	-35.42	-18.56
62.85	-11.05	-10.51	-11.61	-35.03	-20.14
63.00	-10.45	-9.97	-10.97	-35.28	-21.92
63.15	-9.82	-9.28	-10.39	-33.71	-19.84
63.30	-11.74	-11.25	-12.27	-36.41	-22.34
63.45	-11.74	-11.32	-12.19	-37.79	-27.28
63.60	-10.36	-9.92	-10.82	-36.09	-24.17
63.75	-9.94	-9.48	-10.43	-35.13	-22.59
63.90	-11.16	-10.70	-11.64	-36.53	-23.86
64.05	-11.67	-11.28	-12.08	-38.32	-30.10
64.20	-11.39	-11.02	-11.78	-38.66	-32.74
64.35	-10.66	-10.27	-11.06	-37.55	-28.42
64.50	-10.07	-9.66	-10.50	-36.38	-25.61
64.65	-10.48	-10.09	-10.89	-37.21	-27.46
64.80	-11.14	-10.79	-11.51	-38.78	-34.14
64.95	-11.84	-11.45	-12.24	-38.65	-31.83
65.10	-11.77	-11.34	-12.22	-37.70	-26.84
65.25	-11.23	-10.83	-11.64	-37.83	-28.49
65.40	-10.65	-10.30	-11.03	-38.17	-31.30
65.55	-10.41	-10.07	-10.75	-38.57	-34.14
65.70	-11.02	-10.62	-11.44	-37.52	-27.60
65.85	-11.26	-10.83	-11.72	-37.11	-25.56
66.00	-11.36	-10.90	-11.85	-36.57	-23.57
66.15	-12.09	-11.63	-12.57	-37.43	-25.10
66.30	-12.61	-12.18	-13.07	-38.46	-29.02
66.45	-11.81	-11.38	-12.27	-37.65	-26.55
66.60	-10.68	-10.24	-11.13	-36.44	-24.57
66.75	-10.44	-10.00	-10.91	-36.09	-24.04
66.90	-11.25	-10.85	-11.68	-37.66	-27.67
67.05	-12.45	-11.95	-12.98	-36.99	-22.74
67.20	-11.24	-10.73	-11.79	-35.55	-21.02
67.35	-10.94	-10.44	-11.47	-35.54	-21.59
67.50	-12.22	-11.59	-12.90	-34.71	-17.09
67.65	-11.77	-11.19	-12.38	-35.08	-18.82
67.80	-11.44	-10.89	-12.03	-35.08	-19.48
67.95	-11.22	-10.70	-11.76	-35.46	-20.84
68.10	-11.15	-10.61	-11.72	-35.04	-19.98
68.25	-10.99	-10.40	-11.63	-33.99	-18.05
68.40	-11.77	-11.23	-12.34	-35.64	-20.17
68.55	-12.18	-11.62	-12.78	-35.67	-19.43
68.70	-11.89	-11.40	-12.41	-36.62	-22.67
68.85	-12.08	-11.59	-12.60	-36.81	-22.89
69.00	-12.43	-11.91	-12.99	-36.61	-21.56

TABLE IV (cont.)

69.15	-11.89	-11.34	-12.47	-35.68	-20.04
69.30	-11.51	-10.99	-12.07	-35.67	-20.75
69.45	-11.34	-10.81	-11.90	-35.36	-20.34
69.60	-12.12	-11.54	-12.74	-35.33	-18.72
69.75	-12.20	-11.57	-12.87	-34.74	-17.20
69.90	-11.53	-10.90	-12.22	-33.98	-16.94
70.05	-10.76	-10.22	-11.33	-34.69	-19.96
70.20	-10.98	-10.43	-11.57	-34.64	-19.40
70.35	-9.95	-9.37	-10.57	-33.20	-18.61
70.50	-10.09	-9.53	-10.69	-33.68	-19.22
70.65	-10.81	-10.28	-11.37	-34.84	-20.20
70.80	-10.83	-10.31	-11.38	-35.01	-20.54
70.95	-10.89	-10.37	-11.44	-35.15	-20.75
71.10	-10.23	-9.74	-10.75	-34.93	-21.55
71.25	-11.00	-10.53	-11.48	-36.24	-23.33
71.40	-10.70	-10.21	-11.23	-35.35	-21.59
71.55	-10.58	-10.11	-11.07	-35.76	-22.86
71.70	-11.19	-10.74	-11.66	-36.68	-24.26
71.85	-11.03	-10.61	-11.46	-37.23	-26.43
72.00	-9.93	-9.50	-10.39	-35.73	-24.08
72.15	-10.63	-10.13	-11.17	-35.09	-21.11
72.30	-12.08	-11.59	-12.59	-36.89	-23.16
72.45	-11.48	-11.05	-11.93	-37.41	-26.21
72.60	-11.00	-10.59	-11.42	-37.38	-27.08
72.75	-10.76	-10.35	-11.19	-37.07	-26.42
72.90	-10.78	-10.37	-11.22	-37.09	-26.42
73.05	-10.79	-10.44	-11.15	-38.63	-33.74
73.20	-10.92	-10.58	-11.27	-38.95	-36.01
73.35	-10.82	-10.44	-11.21	-37.85	-29.41
73.50	-10.82	-10.43	-11.23	-37.54	-28.06
73.65	-11.17	-10.78	-11.57	-38.00	-29.41
73.80	-11.36	-10.98	-11.75	-38.34	-30.82
73.95	-11.32	-10.94	-11.72	-38.31	-30.73
74.10	-10.98	-10.61	-11.36	-38.27	-31.21
74.25	-10.86	-10.44	-11.31	-36.83	-25.40
74.40	-11.09	-10.61	-11.59	-36.11	-22.78
74.55	-11.04	-10.55	-11.56	-35.77	-21.96
74.70	-11.19	-10.70	-11.72	-35.86	-21.89
74.85	-11.06	-10.64	-11.51	-37.04	-25.71
75.00	-11.20	-10.68	-11.75	-35.47	-20.90
75.15	-11.53	-10.95	-12.15	-34.72	-18.49
75.30	-10.48	-10.00	-10.99	-35.37	-22.09
75.45	-10.59	-10.17	-11.03	-36.73	-25.61
75.60	-11.94	-11.40	-12.51	-35.81	-20.29
75.75	-11.58	-11.08	-12.11	-36.12	-21.82
75.90	-11.03	-10.53	-11.55	-35.66	-21.72
76.05	-10.75	-10.21	-11.32	-34.63	-19.85
76.20	-11.47	-10.90	-12.07	-34.91	-19.03
76.35	-11.64	-11.04	-12.28	-34.62	-18.05
76.50	-11.49	-10.92	-12.09	-34.89	-18.96
76.65	-11.32	-10.75	-11.94	-34.59	-18.63
76.80	-12.23	-11.59	-12.91	-34.59	-16.81
76.95	-11.73	-11.11	-12.39	-34.34	-17.29
77.10	-11.64	-11.14	-12.17	-36.19	-21.89
77.25	-11.81	-11.25	-12.40	-35.45	-19.64
77.40	-11.79	-11.22	-12.39	-35.28	-19.25
77.55	-11.37	-10.86	-11.91	-35.77	-21.30
77.70	-11.50	-10.85	-12.21	-33.68	-16.41
77.85	-11.84	-11.15	-12.58	-33.51	-15.42
78.00	-12.37	-11.70	-13.10	-34.27	-15.84
78.15	-12.74	-12.12	-13.41	-35.36	-17.55
78.30	-12.82	-12.29	-13.39	-36.83	-21.49
78.45	-12.20	-11.66	-12.77	-36.12	-20.60
78.60	-11.72	-11.23	-12.25	-36.36	-22.23
78.75	-11.85	-11.24	-12.51	-34.55	-17.48
78.90	-11.62	-11.04	-12.24	-34.87	-18.65

TABLE IV (cont.)

79.05	-12.53	-12.01	-13.09	-36.69	-21.62
79.20	-12.48	-11.83	-13.19	-34.68	-16.49
79.35	-11.87	-11.29	-12.49	-35.05	-18.56
79.50	-11.69	-11.19	-12.21	-36.36	-22.30
79.65	-11.82	-11.33	-12.33	-36.68	-23.01
79.80	-11.63	-11.06	-12.24	-35.05	-19.03
79.95	-11.82	-11.24	-12.44	-35.05	-18.65
80.10	-12.61	-11.99	-13.27	-35.26	-17.57
80.25	-10.50	-9.96	-11.07	-34.45	-19.98
80.40	-10.71	-10.05	-11.42	-32.80	-16.35
80.55	-12.49	-11.83	-13.21	-34.52	-16.14
80.70	-10.28	-9.71	-10.88	-33.73	-18.96
80.85	-10.42	-9.89	-11.00	-34.35	-19.90
81.00	-11.05	-10.51	-11.61	-35.03	-20.14
81.15	-11.74	-11.25	-12.27	-36.41	-22.34
81.30	-9.94	-9.48	-10.43	-35.13	-22.59
81.45	-11.39	-11.02	-11.78	-38.66	-32.74
81.60	-10.48	-10.09	-10.89	-37.21	-27.46
81.75	-11.77	-11.34	-12.22	-37.70	-26.84
81.90	-10.41	-10.07	-10.75	-38.57	-34.14
82.05	-11.36	-10.90	-11.85	-36.57	-23.57
82.20	-11.81	-11.38	-12.27	-37.65	-26.55
82.35	-11.25	-10.85	-11.68	-37.66	-27.67
82.50	-10.94	-10.44	-11.47	-35.54	-21.59
82.65	-11.44	-10.89	-12.03	-35.08	-19.48
82.80	-10.99	-10.40	-11.63	-33.99	-18.05
82.95	-11.89	-11.40	-12.41	-36.62	-22.67
83.10	-11.89	-11.34	-12.47	-35.68	-20.04
83.25	-12.12	-11.54	-12.74	-35.33	-18.72
83.40	-10.76	-10.22	-11.33	-34.69	-19.96
83.55	-10.09	-9.53	-10.69	-33.68	-19.22
83.70	-10.89	-10.37	-11.44	-35.15	-20.75
83.85	-10.70	-10.21	-11.23	-35.35	-21.59
84.00	-11.03	-10.61	-11.46	-37.23	-26.43
84.15	-12.08	-11.59	-12.59	-36.89	-23.16
84.30	-10.76	-10.35	-11.19	-37.07	-26.42
84.45	-10.92	-10.58	-11.27	-38.95	-36.01
84.60	-11.17	-10.78	-11.57	-38.00	-29.41
84.75	-10.98	-10.61	-11.36	-38.27	-31.21
84.90	-11.04	-10.55	-11.56	-35.77	-21.96
85.05	-11.20	-10.68	-11.75	-35.47	-20.90
85.20	-10.59	-10.17	-11.03	-36.73	-25.61
85.35	-11.03	-10.53	-11.55	-35.66	-21.72
85.50	-11.64	-11.04	-12.28	-34.62	-18.05
85.65	-12.23	-11.59	-12.91	-34.59	-16.81
85.80	-11.81	-11.25	-12.40	-35.45	-19.64
85.95	-11.50	-10.85	-12.21	-33.68	-16.41
86.10	-12.74	-12.12	-13.41	-35.36	-17.55
86.25	-11.72	-11.23	-12.25	-36.36	-22.23
86.40	-12.53	-12.01	-13.09	-36.69	-21.62
86.55	-11.69	-11.19	-12.21	-36.36	-22.30
86.70	-11.82	-11.24	-12.44	-35.05	-18.65
86.85	-10.71	-10.05	-11.42	-32.80	-16.35
87.00	-10.42	-9.89	-11.00	-34.35	-19.90
87.15	-9.94	-9.48	-10.43	-35.13	-22.59
87.30	-11.77	-11.34	-12.22	-37.70	-26.84
87.45	-11.81	-11.38	-12.27	-37.65	-26.55
87.60	-11.44	-10.89	-12.03	-35.08	-19.48
87.75	-11.89	-11.34	-12.47	-35.68	-20.04
87.90	-10.09	-9.53	-10.69	-33.68	-19.22
88.05	-11.03	-10.61	-11.46	-37.23	-26.43
88.20	-10.92	-10.58	-11.27	-38.95	-36.01
88.35	-11.04	-10.55	-11.56	-35.77	-21.96
88.50	-11.03	-10.53	-11.55	-35.66	-21.72
88.65	-11.81	-11.25	-12.40	-35.45	-19.64
88.80	-11.72	-11.23	-12.25	-36.36	-22.23

TABLE IV (cont.)

88.95	-11.82	-11.24	-12.44	-35.05	-18.65
89.10	-9.94	-9.48	-10.43	-35.13	-22.59
89.25	-11.44	-10.89	-12.03	-35.08	-19.48
89.40	-11.03	-10.61	-11.46	-37.23	-26.43
89.55	-11.03	-10.53	-11.55	-35.66	-21.72
89.70	-11.82	-11.24	-12.44	-35.05	-18.65
89.85	-11.03	-10.61	-11.46	-37.23	-26.43
90.00	-11.03	-10.61	-11.46	-37.23	-26.43

TABLE V

PRINTED OUTPUT OF RETURN LOSS FOR 10 dB ATTENUATOR WITH SHORTED OUTPUT USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 10 dB ATTENUATOR WITH SHORT

Frequency (GHz)	Return (dB)	Max Ret (dB)	Min Ret (dB)	Uncer (dB)	S22 (dB)
60.00	-18.11	-17.32	-18.97	-38.57	-18.70
60.15	-25.41	-23.88	-27.28	-39.68	-17.57
60.30	-19.82	-18.88	-20.87	-38.70	-16.18
60.45	-19.77	-18.86	-20.79	-38.92	-18.03
60.60	-21.07	-20.07	-22.20	-39.35	-19.98
60.75	-20.77	-19.77	-21.90	-39.01	-16.86
60.90	-20.27	-19.29	-21.37	-38.74	-15.63
61.05	-19.51	-18.60	-20.53	-38.63	-16.35
61.20	-19.25	-18.37	-20.23	-38.68	-17.20
61.35	-21.07	-20.04	-22.24	-39.08	-16.90
61.50	-26.43	-24.73	-28.56	-39.70	-16.14
61.65	-20.60	-19.61	-21.72	-38.95	-16.59
61.80	-18.71	-17.87	-19.64	-38.58	-17.62
61.95	-19.55	-18.67	-20.53	-38.98	-18.96
62.10	-19.47	-18.59	-20.45	-38.91	-18.51
62.25	-17.95	-17.15	-18.83	-38.27	-17.25
62.40	-18.66	-17.85	-19.55	-38.88	-19.90
62.55	-22.47	-21.33	-23.78	-39.52	-19.98
62.70	-25.85	-24.25	-27.81	-39.74	-18.56
62.85	-20.64	-19.68	-21.72	-39.29	-20.14
63.00	-18.28	-17.52	-19.12	-39.02	-21.92
63.15	-17.78	-17.03	-18.61	-38.64	-19.84
63.30	-22.19	-21.09	-23.45	-39.61	-22.34
63.45	-24.30	-22.96	-25.89	-39.86	-27.28
63.60	-19.34	-18.52	-20.25	-39.40	-24.17
63.75	-18.58	-17.80	-19.43	-39.15	-22.59
63.90	-20.92	-19.96	-22.00	-39.56	-23.86
64.05	-23.31	-22.11	-24.71	-39.87	-30.10
64.20	-21.32	-20.35	-22.42	-39.85	-32.74
64.35	-19.01	-18.23	-19.86	-39.60	-28.42
64.50	-18.13	-17.40	-18.92	-39.33	-25.61
64.65	-18.69	-17.93	-19.52	-39.52	-27.46
64.80	-20.92	-19.99	-21.96	-39.86	-34.14
64.95	-23.53	-22.30	-24.96	-39.90	-31.83
65.10	-23.53	-22.29	-24.98	-39.83	-26.84
65.25	-21.04	-20.08	-22.11	-39.75	-28.49
65.40	-19.16	-18.38	-20.01	-39.72	-31.30
65.55	-18.53	-17.80	-19.31	-39.76	-34.14
65.70	-19.73	-18.89	-20.66	-39.62	-27.60
65.85	-20.62	-19.70	-21.66	-39.61	-25.56
66.00	-21.39	-20.38	-22.53	-39.59	-23.57
66.15	-23.63	-22.37	-25.10	-39.79	-25.10
66.30	-25.98	-24.39	-27.92	-39.92	-29.02
66.45	-21.71	-20.68	-22.88	-39.73	-26.55
66.60	-18.79	-18.01	-19.64	-39.35	-24.57
66.75	-18.24	-17.50	-19.05	-39.22	-24.04
66.90	-20.16	-19.29	-21.13	-39.66	-27.67
67.05	-24.77	-23.35	-26.47	-39.79	-22.74
67.20	-21.33	-20.31	-22.48	-39.45	-21.02
67.35	-20.72	-19.76	-21.79	-39.41	-21.59
67.50	-22.57	-21.40	-23.93	-39.35	-17.09
67.65	-21.94	-20.85	-23.19	-39.39	-18.82
67.80	-20.56	-19.60	-21.64	-39.22	-19.48
67.95	-19.58	-18.72	-20.54	-39.17	-20.84
68.10	-19.42	-18.56	-20.37	-39.06	-19.98
68.25	-19.96	-19.04	-20.99	-38.97	-18.05
68.40	-21.31	-20.29	-22.47	-39.39	-20.17
68.55	-22.39	-21.25	-23.70	-39.48	-19.43
68.70	-22.60	-21.46	-23.91	-39.66	-22.67
68.85	-23.06	-21.87	-24.44	-39.70	-22.89
69.00	-24.02	-22.70	-25.57	-39.72	-21.56

TABLE V (cont.)

69.15	-21.99	-20.90	-23.23	-39.47	-20.04
69.30	-20.17	-19.25	-21.19	-39.27	-20.75
69.45	-20.20	-19.28	-21.23	-39.24	-20.34
69.60	-21.68	-20.61	-22.90	-39.34	-18.72
69.75	-21.83	-20.74	-23.09	-39.25	-17.20
69.90	-21.27	-20.23	-22.46	-39.12	-16.94
70.05	-22.70	-21.53	-24.05	-39.54	-19.96
70.20	-20.62	-19.65	-21.70	-39.23	-19.40
70.35	-18.30	-17.50	-19.18	-38.61	-18.61
70.50	-18.41	-17.61	-19.29	-38.73	-19.22
70.65	-20.21	-19.29	-21.24	-39.23	-20.20
70.80	-21.23	-20.22	-22.38	-39.41	-20.54
70.95	-20.15	-19.24	-21.17	-39.26	-20.75
71.10	-19.70	-18.83	-20.67	-39.26	-21.55
71.25	-21.19	-20.20	-22.30	-39.56	-23.33
71.40	-21.02	-20.04	-22.13	-39.45	-21.59
71.55	-20.11	-19.21	-21.10	-39.41	-22.86
71.70	-22.07	-20.99	-23.29	-39.68	-24.26
71.85	-20.66	-19.73	-21.69	-39.65	-26.43
72.00	-18.09	-17.36	-18.89	-39.20	-24.08
72.15	-19.57	-18.71	-20.53	-39.19	-21.11
72.30	-24.26	-22.92	-25.86	-39.78	-23.16
72.45	-22.73	-21.59	-24.04	-39.78	-26.21
72.60	-20.84	-19.90	-21.89	-39.69	-27.08
72.75	-20.55	-19.64	-21.58	-39.64	-26.42
72.90	-20.52	-19.61	-21.54	-39.64	-26.42
73.05	-20.42	-19.54	-21.41	-39.84	-33.74
73.20	-20.71	-19.80	-21.72	-39.88	-36.01
73.35	-20.32	-19.43	-21.30	-39.73	-29.41
73.50	-20.38	-19.49	-21.37	-39.69	-28.06
73.65	-21.33	-20.35	-22.43	-39.79	-29.41
73.80	-22.00	-20.95	-23.19	-39.84	-30.82
73.95	-21.89	-20.85	-23.07	-39.84	-30.73
74.10	-20.81	-19.89	-21.84	-39.80	-31.21
74.25	-20.28	-19.38	-21.27	-39.57	-25.40
74.40	-20.47	-19.55	-21.51	-39.45	-22.78
74.55	-21.09	-20.10	-22.20	-39.48	-21.96
74.70	-21.50	-20.47	-22.67	-39.52	-21.89
74.85	-20.96	-20.00	-22.03	-39.65	-25.71
75.00	-21.66	-20.61	-22.86	-39.48	-20.90
75.15	-22.34	-21.20	-23.65	-39.42	-18.49
75.30	-19.54	-18.68	-20.48	-39.27	-22.09
75.45	-19.45	-18.62	-20.36	-39.50	-25.61
75.60	-24.07	-22.74	-25.65	-39.68	-20.29
75.75	-22.34	-21.22	-23.62	-39.60	-21.82
75.90	-20.16	-19.26	-21.17	-39.34	-21.72
76.05	-19.66	-18.78	-20.65	-39.09	-19.85
76.20	-20.96	-19.96	-22.09	-39.25	-19.03
76.35	-22.36	-21.22	-23.68	-39.39	-18.05
76.50	-21.47	-20.42	-22.66	-39.33	-18.96
76.65	-21.56	-20.50	-22.76	-39.32	-18.63
76.80	-22.58	-21.40	-23.95	-39.33	-16.81
76.95	-22.03	-20.91	-23.31	-39.29	-17.29
77.10	-21.56	-20.53	-22.73	-39.53	-21.89
77.25	-21.20	-20.19	-22.35	-39.34	-19.64
77.40	-21.11	-20.10	-22.26	-39.30	-19.25
77.55	-21.05	-20.06	-22.16	-39.43	-21.30
77.70	-21.48	-20.41	-22.70	-39.11	-16.41
77.85	-22.14	-20.99	-23.46	-39.14	-15.42
78.00	-22.79	-21.58	-24.20	-39.29	-15.84
78.15	-23.46	-22.18	-24.95	-39.50	-17.55
78.30	-23.78	-22.49	-25.29	-39.70	-21.49
78.45	-23.16	-21.94	-24.58	-39.62	-20.60
78.60	-22.01	-20.93	-23.24	-39.59	-22.23
78.75	-20.75	-19.75	-21.87	-39.07	-17.48
78.90	-21.25	-20.22	-22.41	-39.27	-18.65

TABLE V (cont.)

79.05	-23.66	-22.39	-25.15	-39.70	-21.62
79.20	-22.98	-21.76	-24.41	-39.37	-16.49
79.35	-21.33	-20.30	-22.51	-39.28	-18.56
79.50	-21.11	-20.12	-22.23	-39.50	-22.30
79.65	-20.86	-19.90	-21.94	-39.51	-23.01
79.80	-20.93	-19.94	-22.06	-39.25	-19.03
79.95	-21.71	-20.64	-22.94	-39.34	-18.65
80.10	-25.41	-23.88	-27.28	-39.68	-17.57
80.25	-21.07	-20.07	-22.20	-39.35	-19.98
80.40	-19.51	-18.60	-20.53	-38.63	-16.35
80.55	-26.43	-24.73	-28.56	-39.70	-16.14
80.70	-19.55	-18.67	-20.53	-38.98	-18.96
80.85	-18.66	-17.85	-19.55	-38.88	-19.90
81.00	-20.64	-19.68	-21.72	-39.29	-20.14
81.15	-22.19	-21.09	-23.45	-39.61	-22.34
81.30	-18.58	-17.80	-19.43	-39.15	-22.59
81.45	-21.32	-20.35	-22.42	-39.85	-32.74
81.60	-18.69	-17.93	-19.52	-39.52	-27.46
81.75	-23.53	-22.29	-24.98	-39.83	-26.84
81.90	-18.53	-17.80	-19.31	-39.76	-34.14
82.05	-21.39	-20.38	-22.53	-39.59	-23.57
82.20	-21.71	-20.68	-22.88	-39.73	-26.55
82.35	-20.16	-19.29	-21.13	-39.66	-27.67
82.50	-20.72	-19.76	-21.79	-39.41	-21.59
82.65	-20.56	-19.60	-21.64	-39.22	-19.48
82.80	-19.96	-19.04	-20.99	-38.97	-18.05
82.95	-22.60	-21.46	-23.91	-39.66	-22.67
83.10	-21.99	-20.90	-23.23	-39.47	-20.04
83.25	-21.68	-20.61	-22.90	-39.34	-18.72
83.40	-22.70	-21.53	-24.05	-39.54	-19.96
83.55	-18.41	-17.61	-19.29	-38.73	-19.22
83.70	-20.15	-19.24	-21.17	-39.26	-20.75
83.85	-21.02	-20.04	-22.13	-39.45	-21.59
84.00	-20.66	-19.73	-21.69	-39.65	-26.43
84.15	-24.26	-22.92	-25.86	-39.78	-23.16
84.30	-20.55	-19.64	-21.58	-39.64	-26.42
84.45	-20.71	-19.80	-21.72	-39.88	-36.01
84.60	-21.33	-20.35	-22.43	-39.79	-29.41
84.75	-20.81	-19.89	-21.84	-39.80	-31.21
84.90	-21.09	-20.10	-22.20	-39.48	-21.96
85.05	-21.66	-20.61	-22.86	-39.48	-20.90
85.20	-19.45	-18.62	-20.36	-39.50	-25.61
85.35	-20.16	-19.26	-21.17	-39.34	-21.72
85.50	-22.36	-21.22	-23.68	-39.39	-18.05
85.65	-22.58	-21.40	-23.95	-39.33	-16.81
85.80	-21.20	-20.19	-22.35	-39.34	-19.64
85.95	-21.48	-20.41	-22.70	-39.11	-16.41
86.10	-23.46	-22.18	-24.95	-39.50	-17.55
86.25	-22.01	-20.93	-23.24	-39.59	-22.23
86.40	-23.66	-22.39	-25.15	-39.70	-21.62
86.55	-21.11	-20.12	-22.23	-39.50	-22.30
86.70	-21.71	-20.64	-22.94	-39.34	-18.65
86.85	-19.51	-18.60	-20.53	-38.63	-16.35
87.00	-18.66	-17.85	-19.55	-38.88	-19.90
87.15	-18.58	-17.80	-19.43	-39.15	-22.59
87.30	-23.53	-22.29	-24.98	-39.83	-26.84
87.45	-21.71	-20.68	-22.88	-39.73	-26.55
87.60	-20.56	-19.60	-21.64	-39.22	-19.48
87.75	-21.99	-20.90	-23.23	-39.47	-20.04
87.90	-18.41	-17.61	-19.29	-38.73	-19.22
88.05	-20.66	-19.73	-21.69	-39.65	-26.43
88.20	-20.71	-19.80	-21.72	-39.88	-36.01
88.35	-21.09	-20.10	-22.20	-39.48	-21.96
88.50	-20.16	-19.26	-21.17	-39.34	-21.72
88.65	-21.20	-20.19	-22.35	-39.34	-19.64
88.80	-22.01	-20.93	-23.24	-39.59	-22.23

TABLE V (cont.)

88.95	-21.71	-20.64	-22.94	-39.34	-18.65
89.10	-18.58	-17.80	-19.43	-39.15	-22.59
89.25	-20.56	-19.60	-21.64	-39.22	-19.48
89.40	-20.66	-19.73	-21.69	-39.65	-26.43
89.55	-20.16	-19.26	-21.17	-39.34	-21.72
89.70	-21.71	-20.64	-22.94	-39.34	-18.65
89.85	-20.66	-19.73	-21.69	-39.65	-26.43
90.00	-20.66	-19.73	-21.69	-39.65	-26.43

TABLE VI

PRINTED OUTPUT OF RETURN LOSS FOR 15 dB ATTENUATOR WITH SHORTED OUTPUT USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 15 dB ATTENUATOR WITH SHORT

Frequency (GHz)	Return (dB)	Max Ret (dB)	Min Ret (dB)	Uncer (dB)	S22 (dB)
60.00	-19.89	-18.98	-20.90	-39.02	-18.70
60.15	-27.41	-25.54	-29.80	-39.79	-17.57
60.30	-26.13	-24.47	-28.17	-39.68	-16.18
60.45	-27.21	-25.38	-29.53	-39.80	-18.03
60.60	-30.54	-28.00	-34.14	-39.92	-19.98
60.75	-29.43	-27.14	-32.54	-39.86	-16.86
60.90	-27.86	-25.89	-30.40	-39.77	-15.63
61.05	-25.85	-24.24	-27.83	-39.66	-16.35
61.20	-24.95	-23.48	-26.72	-39.62	-17.20
61.35	-26.72	-24.97	-28.92	-39.74	-16.90
61.50	-30.36	-27.86	-33.90	-39.88	-16.14
61.65	-26.00	-24.37	-28.02	-39.68	-16.59
61.80	-24.82	-23.37	-26.56	-39.63	-17.62
61.95	-27.15	-25.33	-29.45	-39.81	-18.96
62.10	-25.97	-24.35	-27.95	-39.74	-18.51
62.25	-23.54	-22.25	-25.04	-39.49	-17.25
62.40	-23.72	-22.43	-25.23	-39.63	-19.90
62.55	-27.59	-25.69	-30.01	-39.85	-19.98
62.70	-31.59	-28.78	-35.79	-39.93	-18.56
62.85	-25.92	-24.32	-27.89	-39.78	-20.14
63.00	-23.23	-22.01	-24.64	-39.68	-21.92
63.15	-22.46	-21.32	-23.78	-39.51	-19.84
63.30	-26.53	-24.83	-28.63	-39.85	-22.34
63.45	-31.94	-29.04	-36.33	-39.98	-27.28
63.60	-25.67	-24.12	-27.56	-39.86	-24.17
63.75	-25.35	-23.84	-27.17	-39.81	-22.59
63.90	-28.61	-26.52	-31.37	-39.92	-23.86
64.05	-37.66	-32.73	-50.21	-40.00	-30.10
64.20	-28.11	-26.13	-30.67	-39.97	-32.74
64.35	-24.69	-23.30	-26.35	-39.89	-28.42
64.50	-23.53	-22.29	-24.98	-39.80	-25.61
64.65	-24.30	-22.97	-25.89	-39.86	-27.46
64.80	-27.85	-25.93	-30.32	-39.97	-34.14
64.95	-35.01	-31.13	-42.21	-39.99	-31.83
65.10	-34.45	-30.77	-40.99	-39.99	-26.84
65.25	-27.92	-25.98	-30.42	-39.95	-28.49
65.40	-24.81	-23.41	-26.49	-39.92	-31.30
65.55	-24.21	-22.90	-25.76	-39.94	-34.14
65.70	-26.13	-24.52	-28.12	-39.91	-27.60
65.85	-28.03	-26.06	-30.57	-39.93	-25.56
66.00	-29.07	-26.88	-32.00	-39.93	-23.57
66.15	-32.52	-29.45	-37.31	-39.97	-25.10
66.30	-35.76	-31.60	-44.03	-39.99	-29.02
66.45	-27.11	-25.32	-29.37	-39.92	-26.55
66.60	-23.96	-22.66	-25.49	-39.80	-24.57
66.75	-23.26	-22.05	-24.67	-39.75	-24.04
66.90	-25.66	-24.12	-27.54	-39.90	-27.67
67.05	-35.57	-31.48	-43.57	-39.98	-22.74
67.20	-29.93	-27.54	-33.24	-39.92	-21.02
67.35	-29.64	-27.32	-32.82	-39.92	-21.59
67.50	-34.04	-30.48	-40.17	-39.95	-17.09
67.65	-30.48	-27.95	-34.06	-39.91	-18.82
67.80	-27.52	-25.64	-29.93	-39.84	-19.48
67.95	-25.77	-24.19	-27.69	-39.79	-20.84
68.10	-25.44	-23.92	-27.30	-39.76	-19.98
68.25	-26.24	-24.58	-28.31	-39.75	-18.05
68.40	-28.04	-26.06	-30.61	-39.87	-20.17
68.55	-31.28	-28.55	-35.28	-39.93	-19.43
68.70	-34.20	-30.60	-40.47	-39.98	-22.67
68.85	-34.66	-30.90	-41.45	-39.98	-22.89
69.00	-37.26	-32.50	-48.66	-39.99	-21.56

TABLE VI (cont.)

69.15	-29.14	-26.93	-32.11	-39.90	-20.04
69.30	-26.31	-24.64	-28.37	-39.82	-20.75
69.45	-26.55	-24.84	-28.67	-39.82	-20.34
69.60	-28.72	-26.60	-31.54	-39.87	-18.72
69.75	-28.91	-26.74	-31.81	-39.85	-17.20
69.90	-28.39	-26.32	-31.10	-39.82	-16.94
70.05	-32.53	-29.45	-37.35	-39.95	-19.96
70.20	-27.46	-25.58	-29.85	-39.83	-19.40
70.35	-24.35	-22.97	-26.00	-39.63	-18.61
70.50	-24.56	-23.15	-26.23	-39.67	-19.22
70.65	-27.52	-25.64	-29.92	-39.85	-20.20
70.80	-32.04	-29.10	-36.51	-39.95	-20.54
70.95	-28.72	-26.60	-31.53	-39.89	-20.75
71.10	-27.77	-25.85	-30.25	-39.88	-21.55
71.25	-30.81	-28.21	-34.54	-39.95	-23.33
71.40	-31.53	-28.74	-35.67	-39.95	-21.59
71.55	-28.77	-26.65	-31.59	-39.92	-22.86
71.70	-34.00	-30.47	-40.07	-39.98	-24.26
71.85	-27.55	-25.68	-29.94	-39.93	-26.43
72.00	-23.81	-22.53	-25.31	-39.78	-24.08
72.15	-24.99	-23.54	-26.75	-39.76	-21.11
72.30	-34.99	-31.11	-42.18	-39.98	-23.16
72.45	-33.37	-30.04	-38.84	-39.98	-26.21
72.60	-29.93	-27.55	-33.22	-39.96	-27.08
72.75	-29.63	-27.32	-32.79	-39.96	-26.42
72.90	-29.65	-27.34	-32.82	-39.96	-26.42
73.05	-28.89	-26.76	-31.74	-39.98	-33.74
73.20	-29.78	-27.44	-32.98	-39.99	-36.01
73.35	-28.75	-26.64	-31.54	-39.96	-29.41
73.50	-28.50	-26.44	-31.21	-39.95	-28.06
73.65	-30.84	-28.24	-34.58	-39.98	-29.41
73.80	-33.20	-29.93	-38.52	-39.99	-30.82
73.95	-32.26	-29.27	-36.85	-39.99	-30.73
74.10	-30.25	-27.80	-33.68	-39.98	-31.21
74.25	-28.50	-26.43	-31.20	-39.93	-25.40
74.40	-28.56	-26.48	-31.29	-39.91	-22.78
74.55	-30.05	-27.64	-33.41	-39.93	-21.96
74.70	-31.23	-28.52	-35.20	-39.95	-21.89
74.85	-29.94	-27.56	-33.24	-39.95	-25.71
75.00	-31.72	-28.87	-35.98	-39.95	-20.90
75.15	-34.78	-30.97	-41.72	-39.97	-18.49
75.30	-26.62	-24.90	-28.75	-39.85	-22.09
75.45	-25.84	-24.26	-27.76	-39.88	-25.61
75.60	-35.12	-31.19	-42.50	-39.97	-20.29
75.75	-31.45	-28.68	-35.55	-39.95	-21.82
75.90	-27.38	-25.53	-29.73	-39.87	-21.72
76.05	-26.54	-24.84	-28.67	-39.81	-19.85
76.20	-28.62	-26.52	-31.40	-39.87	-19.03
76.35	-34.22	-30.60	-40.52	-39.96	-18.05
76.50	-30.92	-28.28	-34.72	-39.92	-18.96
76.65	-30.67	-28.10	-34.34	-39.91	-18.63
76.80	-33.77	-30.30	-39.63	-39.95	-16.81
76.95	-31.94	-29.02	-36.35	-39.92	-17.29
77.10	-30.19	-27.74	-33.62	-39.93	-21.89
77.25	-29.28	-27.04	-32.31	-39.89	-19.64
77.40	-29.06	-26.86	-32.00	-39.88	-19.25
77.55	-28.75	-26.63	-31.57	-39.90	-21.30
77.70	-29.79	-27.42	-33.06	-39.86	-16.41
77.85	-30.85	-28.22	-34.64	-39.88	-15.42
78.00	-33.18	-29.90	-38.53	-39.93	-15.84
78.15	-34.87	-31.03	-41.93	-39.96	-17.55
78.30	-35.99	-31.74	-44.67	-39.98	-21.49
78.45	-34.86	-31.03	-41.89	-39.97	-20.60
78.60	-30.29	-27.82	-33.76	-39.94	-22.23
78.75	-28.30	-26.26	-30.98	-39.83	-17.48
78.90	-29.17	-26.95	-32.16	-39.88	-18.65

TABLE VI (cont.)

79.05	-37.71	-32.75	-50.44	-39.99	-21.62
79.20	-33.29	-29.97	-38.73	-39.94	-16.49
79.35	-29.22	-26.98	-32.23	-39.88	-18.56
79.50	-28.63	-26.53	-31.39	-39.91	-22.30
79.65	-28.19	-26.19	-30.80	-39.91	-23.01
79.80	-28.29	-26.25	-30.95	-39.86	-19.03
79.95	-29.56	-27.25	-32.72	-39.89	-18.65
80.10	-27.41	-25.54	-29.80	-39.79	-17.57
80.25	-30.54	-28.00	-34.14	-39.92	-19.98
80.40	-25.85	-24.24	-27.83	-39.66	-16.35
80.55	-30.36	-27.86	-33.90	-39.88	-16.14
80.70	-27.15	-25.33	-29.45	-39.81	-18.96
80.85	-23.72	-22.43	-25.23	-39.63	-19.90
81.00	-25.92	-24.32	-27.89	-39.78	-20.14
81.15	-26.53	-24.83	-28.63	-39.85	-22.34
81.30	-25.35	-23.84	-27.17	-39.81	-22.59
81.45	-28.11	-26.13	-30.67	-39.97	-32.74
81.60	-24.30	-22.97	-25.89	-39.86	-27.46
81.75	-34.45	-30.77	-40.99	-39.99	-26.84
81.90	-24.21	-22.90	-25.76	-39.94	-34.14
82.05	-29.07	-26.88	-32.00	-39.93	-23.57
82.20	-27.11	-25.32	-29.37	-39.92	-26.55
82.35	-25.66	-24.12	-27.54	-39.90	-27.67
82.50	-29.64	-27.32	-32.82	-39.92	-21.59
82.65	-27.52	-25.64	-29.93	-39.84	-19.48
82.80	-26.24	-24.58	-28.31	-39.75	-18.05
82.95	-34.20	-30.60	-40.47	-39.98	-22.67
83.10	-29.14	-26.93	-32.11	-39.90	-20.04
83.25	-28.72	-26.60	-31.54	-39.87	-18.72
83.40	-32.53	-29.45	-37.35	-39.95	-19.96
83.55	-24.56	-23.15	-26.23	-39.67	-19.22
83.70	-28.72	-26.60	-31.53	-39.89	-20.75
83.85	-31.53	-28.74	-35.67	-39.95	-21.59
84.00	-27.55	-25.68	-29.94	-39.93	-26.43
84.15	-34.99	-31.11	-42.18	-39.98	-23.16
84.30	-29.63	-27.32	-32.79	-39.96	-26.42
84.45	-29.78	-27.44	-32.98	-39.99	-36.01
84.60	-30.84	-28.24	-34.58	-39.98	-29.41
84.75	-30.25	-27.80	-33.68	-39.98	-31.21
84.90	-30.05	-27.64	-33.41	-39.93	-21.96
85.05	-31.72	-28.87	-35.98	-39.95	-20.90
85.20	-25.84	-24.26	-27.76	-39.88	-25.61
85.35	-27.38	-25.53	-29.73	-39.87	-21.72
85.50	-34.22	-30.60	-40.52	-39.96	-18.05
85.65	-33.77	-30.30	-39.63	-39.95	-16.81
85.80	-29.28	-27.04	-32.31	-39.89	-19.64
85.95	-29.79	-27.42	-33.06	-39.86	-16.41
86.10	-34.87	-31.03	-41.93	-39.96	-17.55
86.25	-30.29	-27.82	-33.76	-39.94	-22.23
86.40	-37.71	-32.75	-50.44	-39.99	-21.62
86.55	-28.63	-26.53	-31.39	-39.91	-22.30
86.70	-29.56	-27.25	-32.72	-39.89	-18.65
86.85	-25.85	-24.24	-27.83	-39.66	-16.35
87.00	-23.72	-22.43	-25.23	-39.63	-19.90
87.15	-25.35	-23.84	-27.17	-39.81	-22.59
87.30	-34.45	-30.77	-40.99	-39.99	-26.84
87.45	-27.11	-25.32	-29.37	-39.92	-26.55
87.60	-27.52	-25.64	-29.93	-39.84	-19.48
87.75	-29.14	-26.93	-32.11	-39.90	-20.04
87.90	-24.56	-23.15	-26.23	-39.67	-19.22
88.05	-27.55	-25.68	-29.94	-39.93	-26.43
88.20	-29.78	-27.44	-32.98	-39.99	-36.01
88.35	-30.05	-27.64	-33.41	-39.93	-21.96
88.50	-27.38	-25.53	-29.73	-39.87	-21.72
88.65	-29.28	-27.04	-32.31	-39.89	-19.64
88.80	-30.29	-27.82	-33.76	-39.94	-22.23

TABLE VI (cont.)

88.95	-29.56	-27.25	-32.72	-39.89	-18.65
89.10	-25.35	-23.84	-27.17	-39.81	-22.59
89.25	-27.52	-25.64	-29.93	-39.84	-19.48
89.40	-27.55	-25.68	-29.94	-39.93	-26.43
89.55	-27.38	-25.53	-29.73	-39.87	-21.72
89.70	-29.56	-27.25	-32.72	-39.89	-18.65
89.85	-27.55	-25.68	-29.94	-39.93	-26.43
90.00	-27.55	-25.68	-29.94	-39.93	-26.43

TABLE VII

PRINTED OUTPUT OF RETURN LOSS FOR 18 dB ATTENUATOR WITH SHORTED OUTPUT USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 18 dB ATTENUATOR WITH SHORT

Frequency (GHz)	Return (dB)	Max Ret (dB)	Min Ret (dB)	Uncer (dB)	S22 (dB)
60.00	-20.28	-19.34	-21.34	-39.10	-13.70
60.15	-25.04	-23.56	-26.83	-39.65	-17.57
60.30	-27.32	-25.46	-29.70	-39.75	-16.18
60.45	-30.32	-27.83	-33.83	-39.90	-18.03
60.60	-32.01	-29.08	-36.47	-39.95	-19.98
60.75	-34.08	-30.51	-40.25	-39.95	-16.86
60.90	-30.07	-27.63	-33.46	-39.86	-15.63
61.05	-28.61	-26.50	-31.41	-39.82	-16.35
61.20	-27.34	-25.48	-29.72	-39.78	-17.20
61.35	-27.04	-25.23	-29.32	-39.76	-16.90
61.50	-27.61	-25.69	-30.07	-39.77	-16.14
61.65	-26.32	-24.64	-28.42	-39.70	-16.59
61.80	-26.50	-24.79	-28.64	-39.75	-17.62
61.95	-31.31	-28.57	-35.33	-39.93	-18.96
62.10	-28.94	-26.77	-31.84	-39.87	-18.51
62.25	-25.81	-24.21	-27.77	-39.69	-17.25
62.40	-25.46	-23.93	-27.32	-39.75	-19.90
62.55	-26.93	-25.16	-29.17	-39.83	-19.98
62.70	-28.24	-26.21	-30.89	-39.85	-18.56
62.85	-26.05	-24.42	-28.05	-39.79	-20.14
63.00	-24.86	-23.42	-26.58	-39.78	-21.92
63.15	-24.16	-22.81	-25.75	-39.67	-19.84
63.30	-26.41	-24.73	-28.49	-39.85	-22.34
63.45	-29.30	-27.06	-32.31	-39.96	-27.28
63.60	-27.64	-25.75	-30.07	-39.91	-24.17
63.75	-28.32	-26.29	-30.97	-39.91	-22.59
63.90	-32.61	-29.51	-37.48	-39.97	-23.86
64.05	-38.83	-33.37	-56.84	-40.00	-30.10
64.20	-29.88	-27.52	-33.13	-39.98	-32.74
64.35	-26.81	-25.08	-28.98	-39.93	-28.42
64.50	-25.72	-24.16	-27.61	-39.88	-25.61
64.65	-26.33	-24.68	-28.37	-39.91	-27.46
64.80	-29.22	-27.01	-32.18	-39.98	-34.14
64.95	-32.94	-29.75	-38.05	-39.99	-31.83
65.10	-33.88	-30.38	-39.81	-39.98	-26.84
65.25	-29.09	-26.90	-32.02	-39.96	-28.49
65.40	-26.63	-24.93	-28.74	-39.95	-31.30
65.55	-26.56	-24.88	-28.65	-39.96	-34.14
65.70	-28.60	-26.52	-31.34	-39.95	-27.60
65.85	-30.76	-28.17	-34.45	-39.96	-25.56
66.00	-31.07	-28.40	-34.94	-39.96	-23.57
66.15	-31.53	-28.74	-35.66	-39.97	-25.10
66.30	-30.72	-28.15	-34.39	-39.97	-29.02
66.45	-27.68	-25.78	-30.11	-39.93	-26.55
66.60	-25.67	-24.12	-27.55	-39.86	-24.57
66.75	-25.23	-23.75	-27.02	-39.84	-24.04
66.90	-27.21	-25.40	-29.49	-39.93	-27.67
67.05	-32.80	-29.65	-37.82	-39.97	-22.74
67.20	-33.18	-29.90	-38.49	-39.96	-21.02
67.35	-33.54	-30.15	-39.17	-39.97	-21.59
67.50	-40.59	-34.26	-120.00	-39.99	-17.09
67.65	-33.79	-30.32	-39.66	-39.96	-18.82
67.80	-30.07	-27.64	-33.44	-39.91	-19.48
67.95	-27.89	-25.94	-30.41	-39.87	-20.84
68.10	-27.89	-25.94	-30.42	-39.86	-19.98
68.25	-28.62	-26.51	-31.40	-39.85	-18.05
68.40	-30.29	-27.81	-33.77	-39.92	-20.17
68.55	-34.03	-30.48	-40.14	-39.96	-19.43
68.70	-36.19	-31.86	-45.21	-39.98	-22.67
68.85	-36.86	-32.26	-47.24	-39.99	-22.89
69.00	-34.48	-30.78	-41.07	-39.97	-21.56

TABLE VII (cont.)

69.15	-30.38	-27.88	-33.91	-39.92	-20.04
69.30	-28.32	-26.29	-30.99	-39.88	-20.75
69.45	-28.54	-26.46	-31.29	-39.88	-20.34
69.60	-31.44	-28.66	-35.54	-39.93	-18.72
69.75	-30.82	-28.20	-34.58	-39.90	-17.20
69.90	-30.37	-27.86	-33.90	-39.89	-16.94
70.05	-29.72	-27.38	-32.94	-39.91	-19.96
70.20	-27.74	-25.82	-30.22	-39.84	-19.40
70.35	-26.23	-24.57	-28.29	-39.76	-18.61
70.50	-26.80	-25.05	-29.00	-39.80	-19.22
70.65	-30.37	-27.87	-33.88	-39.92	-20.20
70.80	-38.28	-33.07	-53.26	-39.99	-20.54
70.95	-33.77	-30.31	-39.62	-39.97	-20.75
71.10	-30.33	-27.85	-33.82	-39.93	-21.55
71.25	-34.61	-30.87	-41.34	-39.98	-23.33
71.40	-37.75	-32.77	-50.61	-39.99	-21.59
71.55	-33.30	-29.99	-38.71	-39.97	-22.86
71.70	-38.22	-33.04	-52.91	-39.99	-24.26
71.85	-29.83	-27.47	-33.07	-39.96	-26.43
72.00	-25.71	-24.15	-27.61	-39.86	-24.08
72.15	-26.62	-24.90	-28.76	-39.84	-21.11
72.30	-32.90	-29.72	-37.99	-39.97	-23.16
72.45	-36.25	-31.90	-45.36	-39.99	-26.21
72.60	-32.83	-29.67	-37.84	-39.98	-27.08
72.75	-35.30	-31.31	-42.89	-39.99	-26.42
72.90	-33.97	-30.44	-39.99	-39.98	-26.42
73.05	-33.75	-30.30	-39.55	-39.99	-33.74
73.20	-35.58	-31.49	-43.57	-40.00	-36.01
73.35	-32.45	-29.40	-37.18	-39.98	-29.41
73.50	-32.08	-29.14	-36.56	-39.98	-28.06
73.65	-34.67	-30.91	-41.44	-39.99	-29.41
73.80	-39.90	-33.93	-78.82	-40.00	-30.32
73.95	-40.79	-34.36	-120.00	-40.00	-30.73
74.10	-33.91	-30.41	-39.86	-39.99	-31.21
74.25	-32.26	-29.27	-36.87	-39.97	-25.40
74.40	-33.41	-30.06	-38.91	-39.97	-22.78
74.55	-35.53	-31.46	-43.48	-39.98	-21.96
74.70	-40.14	-34.05	-120.00	-39.99	-21.89
74.85	-37.10	-32.41	-48.07	-39.99	-25.71
75.00	-35.64	-31.52	-43.74	-39.98	-20.90
75.15	-39.78	-33.87	-72.42	-39.99	-18.49
75.30	-29.27	-27.04	-32.29	-39.92	-22.09
75.45	-28.06	-26.08	-30.61	-39.93	-25.61
75.60	-33.55	-30.16	-39.20	-39.96	-20.29
75.75	-33.39	-30.05	-38.89	-39.97	-21.82
75.90	-30.22	-27.76	-33.66	-39.93	-21.72
76.05	-29.41	-27.14	-32.49	-39.90	-19.85
76.20	-31.83	-28.95	-36.16	-39.94	-19.03
76.35	-40.68	-34.31	-120.00	-39.99	-18.05
76.50	-36.25	-31.89	-45.39	-39.98	-18.96
76.65	-36.03	-31.76	-44.77	-39.97	-18.63
76.80	-41.49	-34.69	-120.00	-39.99	-16.81
76.95	-37.61	-32.69	-50.05	-39.98	-17.29
77.10	-34.66	-30.90	-41.45	-39.98	-21.89
77.25	-32.78	-29.63	-37.78	-39.95	-19.64
77.40	-32.95	-29.74	-38.08	-39.95	-19.25
77.55	-32.63	-29.52	-37.51	-39.96	-21.30
77.70	-33.58	-30.17	-39.26	-39.94	-16.41
77.85	-34.69	-30.91	-41.54	-39.95	-15.42
78.00	-37.39	-32.57	-49.18	-39.97	-15.94
78.15	-37.84	-32.83	-51.07	-39.98	-17.55
78.30	-42.43	-35.11	-120.00	-40.00	-21.49
78.45	-39.15	-33.54	-59.87	-39.99	-20.60
78.60	-34.78	-30.97	-41.71	-39.98	-22.23
78.75	-31.62	-28.79	-35.83	-39.92	-17.48
78.90	-32.16	-29.19	-36.72	-39.94	-18.65

TABLE VII (cont.)

79.05	-38.32	-33.09	-53.47	-39.99	-21.62
79.20	-36.18	-31.85	-45.21	-39.97	-16.49
79.35	-32.92	-29.72	-38.04	-39.95	-18.56
79.50	-32.14	-29.18	-36.67	-39.96	-22.30
79.65	-30.71	-28.13	-34.38	-39.95	-23.01
79.80	-31.20	-28.49	-35.16	-39.93	-19.03
79.95	-31.65	-28.82	-35.88	-39.93	-18.65
80.10	-25.04	-23.56	-26.83	-39.65	-17.57
80.25	-32.01	-29.08	-36.47	-39.95	-19.98
80.40	-28.61	-26.50	-31.41	-39.82	-16.35
80.55	-27.61	-25.69	-30.07	-39.77	-16.14
80.70	-31.31	-28.57	-35.33	-39.93	-18.96
80.85	-25.46	-23.93	-27.32	-39.75	-19.90
81.00	-26.05	-24.42	-28.05	-39.79	-20.14
81.15	-26.41	-24.73	-28.49	-39.85	-22.34
81.30	-28.32	-26.29	-30.97	-39.91	-22.59
81.45	-29.88	-27.52	-33.13	-39.98	-32.74
81.60	-26.33	-24.68	-28.37	-39.91	-27.46
81.75	-33.88	-30.38	-39.81	-39.98	-26.84
81.90	-26.56	-24.88	-28.65	-39.96	-34.14
82.05	-31.07	-28.40	-34.94	-39.96	-23.57
82.20	-27.68	-25.78	-30.11	-39.93	-26.55
82.35	-27.21	-25.40	-29.49	-39.93	-27.67
82.50	-33.54	-30.15	-39.17	-39.97	-21.59
82.65	-30.07	-27.64	-33.44	-39.91	-19.48
82.80	-28.62	-26.51	-31.40	-39.85	-18.05
82.95	-36.19	-31.86	-45.21	-39.98	-22.67
83.10	-30.38	-27.88	-33.91	-39.92	-20.04
83.25	-31.44	-28.66	-35.54	-39.93	-18.72
83.40	-29.72	-27.38	-32.94	-39.91	-19.96
83.55	-26.80	-25.05	-29.00	-39.80	-19.22
83.70	-33.77	-30.31	-39.62	-39.97	-20.75
83.85	-37.75	-32.77	-50.61	-39.99	-21.59
84.00	-29.83	-27.47	-33.07	-39.96	-26.43
84.15	-32.90	-29.72	-37.99	-39.97	-23.16
84.30	-35.30	-31.31	-42.89	-39.99	-26.42
84.45	-35.58	-31.49	-43.57	-40.00	-36.01
84.60	-34.67	-30.91	-41.44	-39.99	-29.41
84.75	-33.91	-30.41	-39.86	-39.99	-31.21
84.90	-35.53	-31.46	-43.48	-39.98	-21.96
85.05	-35.64	-31.52	-43.74	-39.98	-20.90
85.20	-28.06	-26.08	-30.61	-39.93	-25.61
85.35	-30.22	-27.76	-33.66	-39.93	-21.72
85.50	-40.68	-34.31	-120.00	-39.99	-18.05
85.65	-41.49	-34.69	-120.00	-39.99	-16.81
85.80	-32.78	-29.63	-37.78	-39.95	-19.64
85.95	-33.58	-30.17	-39.26	-39.94	-16.41
86.10	-37.84	-32.83	-51.07	-39.98	-17.55
86.25	-34.78	-30.97	-41.71	-39.98	-22.23
86.40	-38.32	-33.09	-53.47	-39.99	-21.62
86.55	-32.14	-29.18	-36.67	-39.96	-22.30
86.70	-31.65	-28.82	-35.88	-39.93	-18.65
86.85	-28.61	-26.50	-31.41	-39.82	-16.35
87.00	-25.46	-23.93	-27.32	-39.75	-19.90
87.15	-28.32	-26.29	-30.97	-39.91	-22.59
87.30	-33.88	-30.38	-39.81	-39.98	-26.84
87.45	-27.68	-25.78	-30.11	-39.93	-26.55
87.60	-30.07	-27.64	-33.44	-39.91	-19.48
87.75	-30.38	-27.88	-33.91	-39.92	-20.04
87.90	-26.80	-25.05	-29.00	-39.80	-19.22
88.05	-29.83	-27.47	-33.07	-39.96	-26.43
88.20	-35.58	-31.49	-43.57	-40.00	-36.01
88.35	-35.53	-31.46	-43.48	-39.98	-21.96
88.50	-30.22	-27.76	-33.66	-39.93	-21.72
88.65	-32.78	-29.63	-37.78	-39.95	-19.64
88.80	-34.78	-30.97	-41.71	-39.98	-22.23

TABLE VII (cont.)

88.95	-31.65	-28.82	-35.88	-39.93	-18.65
89.10	-28.32	-26.29	-30.97	-39.91	-22.59
89.25	-30.07	-27.64	-33.44	-39.91	-19.48
89.40	-29.83	-27.47	-33.07	-39.96	-26.43
89.55	-30.22	-27.76	-33.66	-39.93	-21.72
89.70	-31.65	-28.82	-35.38	-39.93	-18.65
89.85	-29.83	-27.47	-33.07	-39.96	-26.43
90.00	-29.83	-27.47	-33.07	-39.96	-26.43

TABLE IX

PRINTED OUTPUT OF INSERTION LOSS FOR 0 dB ATTENUATOR USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 0 dB ATTENUATOR

Frequency (GHz)	Insertion (dB)	Max Ins (dB)	Min Ins (dB)	Max Unc (dB)	Min Unc (dB)
60.00	-.60	-.23	-.96	.37	-.37
60.30	-.61	-.44	-.78	.17	-.17
60.60	-.35	-.20	-.49	.15	-.15
60.90	-.26	-.08	-.45	.18	-.18
61.20	-.46	-.28	-.64	.18	-.18
61.50	-.59	-.42	-.75	.16	-.16
61.80	-.51	-.36	-.65	.14	-.14
62.10	-.27	-.12	-.41	.15	-.14
62.40	-.48	-.36	-.61	.13	-.13
62.70	-.55	-.37	-.72	.18	-.18
63.00	-.43	-.24	-.61	.19	-.18
63.30	-.46	-.28	-.64	.18	-.18
63.60	-.41	-.11	-.70	.30	-.29
63.90	-.41	-.24	-.57	.17	-.17
64.20	-.39	-.26	-.52	.13	-.13
64.50	-.32	-.18	-.46	.14	-.14
64.80	-.38	-.25	-.50	.12	-.12
65.10	-.35	-.26	-.44	.09	-.09
65.40	-.60	-.50	-.71	.10	-.10
65.70	-.40	-.27	-.53	.13	-.13
66.00	-.35	-.22	-.48	.13	-.13
66.30	-.43	-.33	-.53	.10	-.10
66.60	-.38	-.28	-.49	.10	-.10
66.90	-.35	-.16	-.53	.19	-.19
67.20	-.45	-.36	-.53	.08	-.08
67.50	-.39	-.23	-.54	.16	-.16
67.80	-.53	-.38	-.67	.14	-.14
68.10	-.33	-.24	-.43	.09	-.09
68.40	-.34	-.24	-.44	.10	-.10
68.70	-.36	-.27	-.45	.09	-.09
69.00	-.42	-.32	-.53	.11	-.11
69.30	-.31	-.15	-.47	.16	-.16
69.60	-.35	-.17	-.53	.18	-.18
69.90	-.32	-.15	-.49	.17	-.17
70.20	-.23	-.03	-.42	.20	-.19
70.50	-.42	-.29	-.54	.13	-.13
70.80	-.16	-.02	-.29	.14	-.13
71.10	-.31	-.20	-.42	.11	-.11
71.40	-.34	-.22	-.46	.12	-.12
71.70	-.32	-.22	-.42	.10	-.10
72.00	-.26	-.05	-.47	.21	-.21
72.30	-.25	-.07	-.43	.18	-.18
72.60	-.37	-.26	-.48	.11	-.11
72.90	-.27	-.17	-.37	.10	-.10
73.20	-.46	-.36	-.56	.10	-.10
73.50	-.42	-.32	-.53	.10	-.10
73.80	-.43	-.35	-.51	.08	-.08
74.10	-.33	-.27	-.39	.06	-.06
74.40	-.44	-.37	-.52	.08	-.08
74.70	-.44	-.36	-.53	.09	-.09
75.00	-.40	-.24	-.56	.16	-.16
75.30	-.37	-.25	-.49	.12	-.12
75.60	-.46	-.35	-.56	.11	-.11
75.90	-.42	-.32	-.52	.10	-.10
76.20	-.32	-.22	-.42	.10	-.10
76.50	-.47	-.38	-.57	.09	-.09
76.80	-.53	-.45	-.61	.08	-.08
77.10	-.49	-.40	-.58	.09	-.09
77.40	-.53	-.42	-.63	.10	-.10
77.70	-.59	-.49	-.70	.10	-.10
78.00	-.57	-.46	-.69	.12	-.12

TABLE IX (cont.)

78.30	-.44	-.33	-.55	.11	-.11
78.60	-.38	-.25	-.51	.13	-.13
78.90	-.42	-.32	-.53	.11	-.11
79.20	-.46	-.38	-.54	.08	-.08
79.50	-.55	-.46	-.65	.09	-.09
79.80	-.36	-.23	-.48	.13	-.13
80.10	-.35	-.20	-.49	.15	-.14
80.40	-.25	-.13	-.36	.11	-.11
80.70	-.34	-.23	-.44	.10	-.10
81.00	-.45	-.30	-.60	.15	-.15
81.30	-.61	-.48	-.73	.13	-.12
81.60	-.45	-.31	-.57	.13	-.13
81.90	-.41	-.31	-.51	.10	-.10
82.20	-.41	-.30	-.52	.11	-.11
82.50	-.35	-.25	-.44	.10	-.10
82.80	-.40	-.33	-.47	.07	-.07
83.10	-.40	-.33	-.48	.08	-.08
83.40	-.61	-.53	-.70	.09	-.09
83.70	-.47	-.38	-.56	.09	-.09
84.00	-.35	-.17	-.52	.17	-.17
84.30	-.40	-.14	-.65	.25	-.25
84.60	-.42	-.20	-.65	.23	-.22
84.90	-.37	-.17	-.56	.20	-.19
85.20	-.36	-.20	-.51	.16	-.16
85.50	-.51	-.39	-.63	.12	-.12
85.80	-.53	-.42	-.63	.10	-.10
86.10	-.43	-.34	-.53	.10	-.10
86.40	-.32	-.24	-.41	.08	-.08
86.70	-.30	-.23	-.36	.07	-.07
87.00	-.36	-.28	-.44	.08	-.08
87.30	-.43	-.34	-.52	.09	-.09
87.60	-.42	-.30	-.53	.12	-.11
87.90	-.61	-.53	-.70	.09	-.09
88.20	-.48	-.27	-.68	.21	-.20
88.50	-.42	-.18	-.65	.24	-.23
88.80	-.45	-.22	-.68	.23	-.23
89.10	-.38	-.15	-.61	.23	-.23
89.40	-.26	-.05	-.46	.21	-.21
89.70	-.44	-.27	-.61	.17	-.17
90.00	-.52	-.36	-.68	.16	-.16

TABLE X

PRINTED OUTPUT OF INSERTION LOSS FOR 10 dB ATTENUATOR USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 10 dB ATTENUATOR

Frequency (GHz)	Insertion (dB)	Max Ins (dB)	Min Ins (dB)	Max Unc (dB)	Min Unc (dB)
60.00	-10.75	-10.48	-11.02	.27	-.27
60.30	-10.47	-10.36	-10.58	.11	-.11
60.60	-10.13	-10.04	-10.22	.09	-.09
60.90	-10.19	-10.10	-10.28	.09	-.09
61.20	-10.16	-10.02	-10.30	.14	-.14
61.50	-10.38	-10.21	-10.55	.17	-.17
61.80	-10.46	-10.34	-10.58	.12	-.12
62.10	-10.34	-10.22	-10.46	.12	-.12
62.40	-10.63	-10.47	-10.78	.16	-.16
62.70	-10.62	-10.48	-10.76	.14	-.14
63.00	-10.54	-10.42	-10.66	.12	-.12
63.30	-10.42	-10.24	-10.59	.17	-.17
63.60	-10.46	-10.31	-10.60	.14	-.14
63.90	-10.47	-10.33	-10.61	.14	-.14
64.20	-10.65	-10.53	-10.77	.12	-.12
64.50	-10.63	-10.51	-10.75	.12	-.12
64.80	-10.65	-10.53	-10.76	.11	-.11
65.10	-10.69	-10.59	-10.79	.10	-.10
65.40	-10.93	-10.83	-11.04	.11	-.11
65.70	-10.75	-10.65	-10.85	.10	-.10
66.00	-11.03	-10.94	-11.11	.09	-.09
66.30	-11.12	-11.01	-11.22	.10	-.10
66.60	-10.99	-10.90	-11.09	.10	-.10
66.90	-10.81	-10.71	-10.90	.10	-.10
67.20	-10.91	-10.85	-10.97	.06	-.06
67.50	-11.26	-11.16	-11.37	.11	-.11
67.80	-11.46	-11.34	-11.58	.12	-.12
68.10	-11.34	-11.23	-11.44	.11	-.10
68.40	-11.46	-11.37	-11.55	.09	-.09
68.70	-11.34	-11.27	-11.41	.07	-.07
69.00	-11.46	-11.37	-11.55	.09	-.09
69.30	-11.40	-11.28	-11.51	.12	-.12
69.60	-11.55	-11.42	-11.67	.13	-.13
69.90	-11.49	-11.35	-11.62	.13	-.13
70.20	-10.31	-10.17	-10.45	.14	-.14
70.50	-10.50	-10.41	-10.60	.10	-.10
70.80	-10.28	-10.18	-10.38	.10	-.10
71.10	-10.30	-10.21	-10.39	.09	-.09
71.40	-10.49	-10.41	-10.57	.08	-.08
71.70	-10.44	-10.37	-10.51	.07	-.07
72.00	-10.44	-10.30	-10.58	.14	-.14
72.30	-10.59	-10.46	-10.72	.13	-.13
72.60	-10.61	-10.53	-10.69	.08	-.08
72.90	-10.67	-10.60	-10.75	.07	-.07
73.20	-10.81	-10.71	-10.90	.10	-.10
73.50	-10.82	-10.72	-10.91	.09	-.09
73.80	-10.79	-10.71	-10.87	.08	-.08
74.10	-10.80	-10.74	-10.86	.06	-.06
74.40	-10.82	-10.76	-10.88	.06	-.06
74.70	-10.61	-10.53	-10.70	.08	-.08
75.00	-10.44	-10.31	-10.57	.13	-.13
75.30	-10.58	-10.46	-10.70	.12	-.12
75.60	-10.87	-10.78	-10.96	.09	-.09
75.90	-11.09	-10.99	-11.19	.10	-.10
76.20	-11.02	-10.92	-11.12	.10	-.10
76.50	-11.26	-11.14	-11.39	.13	-.12
76.80	-11.40	-11.27	-11.53	.13	-.13
77.10	-11.53	-11.39	-11.66	.14	-.14
77.40	-11.43	-11.28	-11.58	.15	-.15
77.70	-11.48	-11.32	-11.63	.16	-.16
78.00	-11.65	-11.48	-11.81	.17	-.17

TABLE X (cont.)

78.30	-11.46	-11.30	-11.62	.16	-.16
78.60	-11.52	-11.35	-11.69	.17	-.17
78.90	-11.44	-11.29	-11.60	.16	-.16
79.20	-11.68	-11.53	-11.83	.15	-.15
79.50	-11.89	-11.71	-12.07	.18	-.18
79.80	-11.65	-11.47	-11.82	.17	-.17
80.10	-10.79	-10.61	-10.96	.18	-.17
80.40	-10.81	-10.67	-10.95	.14	-.14
80.70	-10.94	-10.83	-11.06	.12	-.11
81.00	-11.11	-10.99	-11.23	.12	-.12
81.30	-11.05	-10.90	-11.19	.14	-.14
81.60	-10.95	-10.79	-11.10	.16	-.16
81.90	-10.76	-10.64	-10.87	.12	-.12
82.20	-10.83	-10.73	-10.94	.11	-.11
82.50	-10.92	-10.82	-11.01	.10	-.09
82.80	-11.01	-10.92	-11.09	.08	-.08
83.10	-10.89	-10.82	-10.96	.07	-.07
83.40	-11.08	-11.01	-11.15	.07	-.07
83.70	-11.01	-10.92	-11.10	.09	-.09
84.00	-10.73	-10.56	-10.89	.16	-.16
84.30	-10.82	-10.62	-11.02	.20	-.20
84.60	-10.80	-10.61	-10.99	.19	-.19
84.90	-10.82	-10.69	-10.95	.13	-.13
85.20	-10.81	-10.73	-10.89	.08	-.08
85.50	-11.17	-11.10	-11.24	.07	-.07
85.80	-11.27	-11.20	-11.34	.07	-.07
86.10	-11.25	-11.18	-11.31	.07	-.07
86.40	-11.20	-11.13	-11.26	.06	-.06
86.70	-11.25	-11.19	-11.31	.06	-.06
87.00	-11.23	-11.17	-11.29	.06	-.06
87.30	-11.45	-11.37	-11.52	.07	-.07
87.60	-11.42	-11.33	-11.50	.09	-.09
87.90	-11.50	-11.42	-11.59	.08	-.08
88.20	-11.28	-11.11	-11.44	.17	-.17
88.50	-11.28	-11.10	-11.46	.18	-.18
88.80	-11.28	-11.11	-11.46	.18	-.18
89.10	-11.27	-11.10	-11.44	.17	-.17
89.40	-11.28	-11.13	-11.44	.16	-.16
89.70	-11.32	-11.18	-11.46	.14	-.14
90.00	-11.56	-11.42	-11.71	.14	-.14

TABLE XI

PRINTED OUTPUT OF INSERTION LOSS FOR 20 dB ATTENUATOR USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 20 dB ATTENUATOR

Frequency (GHz)	Insertion (dB)	Max Ins (dB)	Min Ins (dB)	Max Unc (dB)	Min Unc (dB)
60.00	-20.52	-20.26	-20.78	.26	-.26
60.30	-20.22	-20.10	-20.33	.12	-.12
60.60	-19.93	-19.85	-20.01	.08	-.08
60.90	-19.96	-19.87	-20.06	.10	-.10
61.20	-19.99	-19.84	-20.14	.15	-.15
61.50	-20.17	-20.00	-20.34	.17	-.17
61.80	-20.34	-20.23	-20.45	.11	-.11
62.10	-20.22	-20.11	-20.33	.11	-.11
62.40	-20.45	-20.29	-20.60	.16	-.16
62.70	-20.41	-20.26	-20.55	.15	-.15
63.00	-20.39	-20.26	-20.53	.14	-.13
63.30	-20.33	-20.15	-20.50	.18	-.17
63.60	-20.35	-20.22	-20.48	.13	-.13
63.90	-20.36	-20.22	-20.50	.14	-.14
64.20	-20.55	-20.43	-20.66	.12	-.12
64.50	-20.54	-20.42	-20.65	.12	-.11
64.80	-20.65	-20.54	-20.75	.11	-.10
65.10	-20.69	-20.58	-20.80	.11	-.11
65.40	-20.96	-20.85	-21.06	.10	-.10
65.70	-20.88	-20.78	-20.97	.10	-.10
66.00	-21.02	-20.92	-21.12	.10	-.10
66.30	-21.08	-20.97	-21.20	.11	-.11
66.60	-20.98	-20.87	-21.09	.11	-.11
66.90	-20.97	-20.86	-21.08	.11	-.11
67.20	-21.06	-21.00	-21.12	.06	-.06
67.50	-21.36	-21.27	-21.46	.10	-.10
67.80	-21.51	-21.40	-21.62	.11	-.11
68.10	-21.40	-21.31	-21.50	.10	-.10
68.40	-21.50	-21.41	-21.58	.09	-.09
68.70	-21.50	-21.43	-21.57	.07	-.07
69.00	-21.65	-21.55	-21.75	.10	-.10
69.30	-21.66	-21.54	-21.77	.12	-.12
69.60	-21.84	-21.72	-21.95	.12	-.12
69.90	-21.70	-21.57	-21.83	.13	-.13
70.20	-20.20	-20.07	-20.34	.13	-.13
70.50	-20.34	-20.26	-20.42	.08	-.08
70.80	-20.09	-20.00	-20.18	.09	-.09
71.10	-20.24	-20.15	-20.32	.08	-.08
71.40	-20.30	-20.24	-20.37	.07	-.07
71.70	-20.42	-20.33	-20.52	.09	-.09
72.00	-20.50	-20.36	-20.64	.14	-.14
72.30	-20.59	-20.48	-20.71	.12	-.12
72.60	-20.68	-20.61	-20.76	.07	-.07
72.90	-20.58	-20.51	-20.65	.07	-.07
73.20	-20.84	-20.77	-20.92	.08	-.08
73.50	-21.01	-20.93	-21.09	.08	-.08
73.80	-20.93	-20.86	-21.00	.07	-.07
74.10	-20.92	-20.86	-20.97	.05	-.05
74.40	-20.93	-20.86	-20.99	.06	-.06
74.70	-20.72	-20.66	-20.77	.06	-.06
75.00	-20.32	-20.22	-20.41	.09	-.09
75.30	-20.59	-20.48	-20.69	.11	-.11
75.60	-20.89	-20.81	-20.96	.08	-.08
75.90	-21.09	-21.02	-21.16	.07	-.07
76.20	-21.01	-20.94	-21.08	.07	-.07
76.50	-21.41	-21.32	-21.50	.09	-.09
76.80	-21.53	-21.44	-21.62	.09	-.09
77.10	-21.51	-21.42	-21.60	.09	-.09
77.40	-21.52	-21.42	-21.61	.10	-.10
77.70	-21.63	-21.53	-21.72	.10	-.10
78.00	-21.72	-21.62	-21.82	.10	-.10

TABLE XI (cont.)

78.30	-21.56	-21.46	-21.65	.10	-.10
78.60	-21.44	-21.34	-21.54	.10	-.10
78.90	-21.57	-21.49	-21.65	.08	-.08
79.20	-21.82	-21.75	-21.89	.07	-.07
79.50	-22.03	-21.94	-22.13	.10	-.10
79.80	-21.72	-21.62	-21.82	.10	-.10
80.10	-20.89	-20.78	-21.01	.11	-.11
80.40	-20.85	-20.76	-20.94	.09	-.09
80.70	-21.18	-21.11	-21.26	.08	-.08
81.00	-21.25	-21.17	-21.32	.08	-.08
81.30	-21.22	-21.11	-21.33	.11	-.11
81.60	-21.04	-20.92	-21.15	.12	-.12
81.90	-20.97	-20.89	-21.05	.08	-.08
82.20	-20.94	-20.87	-21.01	.07	-.07
82.50	-20.96	-20.88	-21.03	.07	-.07
82.80	-21.14	-21.09	-21.20	.06	-.06
83.10	-21.09	-21.03	-21.15	.06	-.06
83.40	-21.07	-21.02	-21.13	.06	-.06
83.70	-21.02	-20.95	-21.09	.07	-.07
84.00	-20.74	-20.61	-20.87	.13	-.13
84.30	-20.85	-20.68	-21.02	.17	-.17
84.60	-20.80	-20.62	-20.98	.18	-.18
84.90	-20.80	-20.65	-20.95	.15	-.15
85.20	-20.96	-20.85	-21.06	.10	-.10
85.50	-21.06	-20.98	-21.14	.08	-.08
85.80	-21.06	-20.98	-21.14	.08	-.08
86.10	-21.09	-21.03	-21.15	.06	-.06
86.40	-21.04	-20.98	-21.10	.06	-.06
86.70	-21.10	-21.04	-21.16	.06	-.06
87.00	-21.26	-21.21	-21.32	.05	-.05
87.30	-21.39	-21.32	-21.46	.07	-.07
87.60	-21.27	-21.20	-21.34	.07	-.07
87.90	-21.37	-21.31	-21.44	.07	-.07
88.20	-21.23	-21.07	-21.38	.16	-.16
88.50	-21.13	-20.96	-21.30	.17	-.17
88.80	-21.19	-21.02	-21.36	.17	-.17
89.10	-21.03	-20.86	-21.20	.17	-.17
89.40	-21.35	-21.19	-21.51	.16	-.16
89.70	-21.36	-21.23	-21.50	.13	-.13
90.00	-21.42	-21.29	-21.56	.14	-.13

TABLE XII

PRINTED OUTPUT OF INSERTION LOSS FOR 30 dB ATTENUATOR USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 30 dB ATTENUATOR

Frequency (GHz)	Insertion (dB)	Max Ins (dB)	Min Ins (dB)	Max Unc (dB)	Min Unc (dB)
60.00	-30.24	-29.98	-30.50	.27	-.26
60.30	-29.80	-29.68	-29.92	.12	-.12
60.60	-29.23	-29.15	-29.31	.08	-.08
60.90	-29.86	-29.75	-29.97	.11	-.11
61.20	-29.54	-29.37	-29.70	.16	-.16
61.50	-29.87	-29.68	-30.05	.18	-.18
61.80	-30.19	-30.08	-30.31	.11	-.11
62.10	-29.89	-29.77	-30.00	.11	-.11
62.40	-29.88	-29.72	-30.04	.16	-.16
62.70	-30.12	-29.96	-30.27	.15	-.15
63.00	-30.00	-29.86	-30.14	.14	-.14
63.30	-29.71	-29.54	-29.89	.18	-.18
63.60	-29.81	-29.69	-29.94	.13	-.13
63.90	-30.04	-29.90	-30.18	.14	-.14
64.20	-30.48	-30.36	-30.61	.13	-.13
64.50	-30.20	-30.08	-30.32	.12	-.12
64.80	-30.32	-30.20	-30.43	.12	-.12
65.10	-30.14	-30.03	-30.26	.12	-.11
65.40	-30.82	-30.71	-30.93	.11	-.11
65.70	-30.58	-30.47	-30.68	.10	-.10
66.00	-31.02	-30.92	-31.11	.10	-.10
66.30	-30.79	-30.67	-30.90	.12	-.12
66.60	-30.75	-30.63	-30.86	.12	-.12
66.90	-30.45	-30.34	-30.56	.11	-.11
67.20	-30.72	-30.67	-30.78	.06	-.06
67.50	-31.20	-31.11	-31.30	.10	-.10
67.80	-31.05	-30.93	-31.16	.11	-.11
68.10	-31.08	-30.97	-31.18	.10	-.10
68.40	-31.50	-31.41	-31.59	.09	-.09
68.70	-31.25	-31.17	-31.32	.08	-.08
69.00	-31.44	-31.33	-31.54	.11	-.11
69.30	-31.19	-31.06	-31.31	.12	-.12
69.60	-31.48	-31.37	-31.60	.11	-.11
69.90	-31.81	-31.68	-31.94	.13	-.13
70.20	-29.83	-29.70	-29.96	.13	-.13
70.50	-30.35	-30.27	-30.43	.08	-.08
70.80	-29.72	-29.63	-29.80	.09	-.09
71.10	-29.47	-29.39	-29.54	.08	-.08
71.40	-30.27	-30.21	-30.34	.06	-.06
71.70	-30.31	-30.21	-30.41	.10	-.10
72.00	-30.07	-29.92	-30.22	.15	-.15
72.30	-30.38	-30.26	-30.49	.12	-.12
72.60	-30.37	-30.30	-30.45	.07	-.07
72.90	-30.05	-29.98	-30.11	.07	-.06
73.20	-30.44	-30.37	-30.51	.07	-.07
73.50	-30.47	-30.40	-30.54	.07	-.07
73.80	-30.12	-30.06	-30.18	.06	-.06
74.10	-30.54	-30.49	-30.60	.05	-.05
74.40	-30.42	-30.37	-30.48	.05	-.05
74.70	-30.25	-30.19	-30.30	.05	-.05
75.00	-30.14	-30.06	-30.21	.08	-.08
75.30	-30.18	-30.08	-30.27	.10	-.10
75.60	-30.65	-30.57	-30.73	.08	-.08
75.90	-30.81	-30.74	-30.88	.07	-.07
76.20	-30.66	-30.59	-30.72	.06	-.06
76.50	-31.04	-30.96	-31.11	.08	-.08
76.80	-31.27	-31.21	-31.34	.07	-.07
77.10	-31.36	-31.29	-31.43	.07	-.07
77.40	-31.08	-31.01	-31.16	.08	-.08
77.70	-31.43	-31.36	-31.51	.08	-.08
78.00	-31.35	-31.27	-31.42	.08	-.08

TABLE XII (cont.)

78.30	-31.16	-31.09	-31.24	.08	-.08
78.60	-31.25	-31.17	-31.33	.08	-.08
78.90	-31.60	-31.53	-31.67	.07	-.07
79.20	-31.69	-31.62	-31.75	.06	-.06
79.50	-31.65	-31.57	-31.73	.08	-.08
79.80	-31.76	-31.68	-31.85	.09	-.09
80.10	-29.97	-29.87	-30.07	.10	-.10
80.40	-30.75	-30.64	-30.86	.11	-.11
80.70	-30.77	-30.68	-30.86	.09	-.09
81.00	-30.31	-30.21	-30.41	.10	-.10
81.30	-30.85	-30.77	-30.93	.08	-.08
81.60	-30.40	-30.31	-30.49	.09	-.09
81.90	-30.04	-29.97	-30.10	.07	-.07
82.20	-30.30	-30.23	-30.38	.08	-.08
82.50	-30.19	-30.12	-30.26	.07	-.07
82.80	-30.14	-30.08	-30.20	.06	-.06
83.10	-30.57	-30.51	-30.62	.06	-.06
83.40	-30.95	-30.89	-31.01	.06	-.06
83.70	-30.46	-30.39	-30.52	.06	-.06
84.00	-30.30	-30.19	-30.41	.11	-.11
84.30	-30.13	-29.96	-30.29	.17	-.17
84.60	-30.29	-30.11	-30.48	.19	-.19
84.90	-30.51	-30.34	-30.67	.16	-.16
85.20	-30.51	-30.40	-30.62	.11	-.11
85.50	-30.68	-30.58	-30.77	.09	-.09
85.80	-30.92	-30.83	-31.02	.09	-.09
86.10	-30.59	-30.53	-30.65	.06	-.06
86.40	-30.36	-30.30	-30.42	.06	-.06
86.70	-30.62	-30.57	-30.67	.05	-.05
87.00	-30.68	-30.62	-30.74	.06	-.06
87.30	-30.99	-30.93	-31.05	.06	-.06
87.60	-30.96	-30.89	-31.03	.07	-.07
87.90	-30.93	-30.86	-30.99	.07	-.07
88.20	-30.78	-30.62	-30.93	.15	-.15
88.50	-30.77	-30.60	-30.94	.17	-.17
88.80	-30.85	-30.68	-31.01	.16	-.16
89.10	-30.42	-30.25	-30.59	.17	-.17
89.40	-30.76	-30.60	-30.91	.16	-.15
89.70	-31.19	-31.05	-31.33	.14	-.14
90.00	-31.04	-30.90	-31.19	.14	-.14

TABLE XIII

PRINTED OUTPUT OF INSERTION LOSS FOR 40 dB ATTENUATOR USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 40 dB ATTENUATOR

Frequency (GHz)	Insertion (dB)	Max Ins (dB)	Min Ins (dB)	Max Unc (dB)	Min Unc (dB)
60.00	-37.22	-36.96	-37.49	.27	-.27
60.30	-36.43	-36.31	-36.56	.13	-.13
60.60	-37.54	-37.45	-37.62	.09	-.09
60.90	-37.54	-37.44	-37.64	.10	-.10
61.20	-37.84	-37.68	-38.00	.16	-.16
61.50	-38.46	-38.27	-38.64	.19	-.18
61.80	-37.42	-37.32	-37.53	.11	-.11
62.10	-37.24	-37.13	-37.36	.12	-.12
62.40	-37.66	-37.50	-37.81	.16	-.16
62.70	-39.22	-39.07	-39.38	.16	-.15
63.00	-37.31	-37.16	-37.45	.14	-.14
63.30	-41.66	-41.48	-41.84	.18	-.18
63.60	-40.32	-40.19	-40.44	.12	-.12
63.90	-39.04	-38.91	-39.17	.13	-.13
64.20	-38.42	-38.30	-38.53	.12	-.12
64.50	-39.18	-39.07	-39.30	.11	-.11
64.80	-38.65	-38.54	-38.76	.11	-.11
65.10	-37.05	-36.93	-37.16	.11	-.11
65.40	-42.67	-42.56	-42.78	.11	-.11
65.70	-40.04	-39.94	-40.14	.10	-.10
66.00	-40.23	-40.13	-40.32	.10	-.10
66.30	-40.90	-40.78	-41.02	.12	-.12
66.60	-38.83	-38.71	-38.95	.12	-.12
66.90	-40.13	-40.02	-40.25	.11	-.11
67.20	-39.97	-39.91	-40.03	.06	-.06
67.50	-39.45	-39.35	-39.56	.10	-.10
67.80	-41.33	-41.22	-41.44	.11	-.11
68.10	-40.62	-40.52	-40.72	.10	-.10
68.40	-45.85	-45.77	-45.94	.09	-.09
68.70	-39.79	-39.72	-39.87	.07	-.07
69.00	-39.19	-39.09	-39.29	.10	-.10
69.30	-42.70	-42.58	-42.82	.12	-.12
69.60	-39.27	-39.15	-39.39	.12	-.12
69.90	-43.82	-43.69	-43.95	.13	-.13
70.20	-40.97	-40.84	-41.10	.13	-.13
70.50	-39.84	-39.75	-39.93	.09	-.09
70.80	-41.43	-41.35	-41.51	.08	-.08
71.10	-38.42	-38.33	-38.50	.08	-.08
71.40	-40.64	-40.58	-40.70	.06	-.06
71.70	-40.31	-40.21	-40.41	.10	-.10
72.00	-40.26	-40.10	-40.41	.15	-.15
72.30	-42.34	-42.23	-42.46	.12	-.12
72.60	-42.92	-42.85	-42.99	.07	-.07
72.90	-39.39	-39.33	-39.46	.07	-.07
73.20	-38.60	-38.52	-38.67	.07	-.07
73.50	-40.80	-40.73	-40.87	.07	-.07
73.80	-37.59	-37.53	-37.65	.06	-.06
74.10	-38.97	-38.91	-39.03	.06	-.06
74.40	-41.71	-41.65	-41.76	.06	-.06
74.70	-38.56	-38.50	-38.62	.06	-.06
75.00	-42.59	-42.51	-42.66	.07	-.07
75.30	-39.39	-39.28	-39.49	.10	-.10
75.60	-40.61	-40.53	-40.69	.08	-.08
75.90	-40.83	-40.75	-40.90	.07	-.07
76.20	-39.63	-39.57	-39.70	.07	-.07
76.50	-40.57	-40.50	-40.63	.07	-.07
76.80	-43.51	-43.44	-43.57	.07	-.07
77.10	-40.24	-40.18	-40.31	.06	-.06
77.40	-42.82	-42.75	-42.88	.07	-.07
77.70	-42.15	-42.09	-42.21	.06	-.06
78.00	-42.71	-42.63	-42.78	.08	-.08

TABLE XIII (cont.)

78.30	-41.83	-41.76	-41.90	.07	-.07
78.60	-41.32	-41.24	-41.40	.08	-.08
78.90	-41.47	-41.39	-41.55	.08	-.08
79.20	-40.91	-40.85	-40.97	.06	-.06
79.50	-42.93	-42.85	-43.01	.08	-.08
79.80	-40.51	-40.42	-40.60	.09	-.09
80.10	-39.11	-39.01	-39.22	.11	-.11
80.40	-42.76	-42.64	-42.87	.11	-.11
80.70	-40.29	-40.19	-40.39	.10	-.10
81.00	-39.11	-39.03	-39.19	.08	-.08
81.30	-39.98	-39.89	-40.07	.09	-.09
81.60	-38.68	-38.60	-38.77	.09	-.09
81.90	-36.97	-36.90	-37.04	.07	-.07
82.20	-39.74	-39.66	-39.81	.08	-.08
82.50	-42.13	-42.05	-42.22	.08	-.08
82.80	-39.53	-39.47	-39.59	.06	-.06
83.10	-37.89	-37.82	-37.96	.07	-.07
83.40	-39.73	-39.67	-39.80	.07	-.07
83.70	-41.54	-41.47	-41.60	.07	-.07
84.00	-38.34	-38.23	-38.45	.11	-.11
84.30	-41.02	-40.85	-41.19	.17	-.17
84.60	-39.06	-38.88	-39.25	.19	-.19
84.90	-39.80	-39.63	-39.96	.17	-.17
85.20	-39.35	-39.23	-39.47	.12	-.12
85.50	-41.24	-41.15	-41.34	.10	-.09
85.80	-40.05	-39.95	-40.15	.10	-.10
86.10	-39.43	-39.37	-39.49	.06	-.06
86.40	-42.59	-42.53	-42.65	.06	-.06
86.70	-39.13	-39.08	-39.19	.05	-.05
87.00	-41.26	-41.20	-41.32	.06	-.06
87.30	-40.09	-40.03	-40.15	.06	-.06
87.60	-38.97	-38.90	-39.04	.07	-.07
87.90	-41.66	-41.59	-41.72	.06	-.06
88.20	-38.67	-38.51	-38.83	.16	-.16
88.50	-42.76	-42.58	-42.93	.17	-.17
88.80	-37.05	-36.88	-37.22	.17	-.17
89.10	-41.00	-40.82	-41.17	.17	-.17
89.40	-39.58	-39.42	-39.74	.16	-.16
89.70	-39.67	-39.52	-39.81	.15	-.15
90.00	-40.81	-40.66	-40.95	.15	-.15

TABLE XIV

PRINTED OUTPUT OF INSERTION LOSS FOR 45 dB ATTENUATOR USING SCHOTTKY DIODE DETECTOR

DEVICE UNDER TEST : 45 dB ATTENUATOR

Frequency (GHz)	Insertion (dB)	Max Ins (dB)	Min Ins (dB)	Max Unc (dB)	Min Unc (dB)
60.00	-37.83	-37.56	-38.09	.27	-.26
60.30	-37.79	-37.65	-37.92	.13	-.13
60.60	-39.42	-39.33	-39.51	.09	-.09
60.90	-41.00	-40.91	-41.09	.09	-.09
61.20	-40.20	-40.04	-40.36	.16	-.16
61.50	-41.27	-41.09	-41.45	.18	-.18
61.80	-39.82	-39.71	-39.92	.11	-.11
62.10	-39.88	-39.77	-39.99	.11	-.11
62.40	-38.03	-37.87	-38.18	.16	-.16
62.70	-39.57	-39.42	-39.72	.15	-.15
63.00	-39.00	-38.86	-39.14	.14	-.14
63.30	-40.61	-40.43	-40.79	.18	-.18
63.60	-39.29	-39.16	-39.42	.13	-.13
63.90	-41.77	-41.64	-41.91	.14	-.13
64.20	-42.84	-42.72	-42.96	.12	-.12
64.50	-42.59	-42.48	-42.70	.11	-.11
64.80	-39.51	-39.40	-39.62	.11	-.11
65.10	-41.11	-41.00	-41.23	.12	-.11
65.40	-42.73	-42.62	-42.84	.11	-.11
65.70	-43.59	-43.49	-43.69	.10	-.10
66.00	-39.76	-39.66	-39.86	.10	-.10
66.30	-39.08	-38.96	-39.20	.12	-.12
66.60	-40.64	-40.52	-40.76	.12	-.12
66.90	-42.27	-42.15	-42.38	.12	-.12
67.20	-45.16	-45.10	-45.21	.06	-.06
67.50	-42.68	-42.59	-42.78	.10	-.10
67.80	-42.27	-42.16	-42.37	.11	-.11
68.10	-44.10	-44.00	-44.19	.10	-.10
68.40	-40.12	-40.03	-40.20	.09	-.09
68.70	-40.24	-40.17	-40.31	.07	-.07
69.00	-44.08	-43.98	-44.19	.11	-.11
69.30	-43.90	-43.78	-44.03	.13	-.13
69.60	-43.33	-43.21	-43.44	.12	-.12
69.90	-44.42	-44.29	-44.55	.13	-.13
70.20	-39.53	-39.40	-39.66	.13	-.13
70.50	-38.50	-38.42	-38.59	.08	-.08
70.80	-39.40	-39.31	-39.49	.09	-.09
71.10	-39.27	-39.20	-39.33	.07	-.07
71.40	-41.83	-41.76	-41.89	.06	-.06
71.70	-39.43	-39.33	-39.53	.10	-.10
72.00	-41.71	-41.56	-41.86	.15	-.15
72.30	-41.03	-40.91	-41.15	.12	-.12
72.60	-40.44	-40.37	-40.51	.07	-.07
72.90	-43.16	-43.09	-43.23	.07	-.07
73.20	-42.30	-42.23	-42.38	.07	-.07
73.50	-45.95	-45.88	-46.01	.07	-.07
73.80	-41.92	-41.86	-41.98	.06	-.06
74.10	-43.73	-43.67	-43.78	.05	-.05
74.40	-41.41	-41.36	-41.46	.05	-.05
74.70	-43.15	-43.09	-43.21	.06	-.06
75.00	-41.82	-41.75	-41.90	.08	-.08
75.30	-39.32	-39.22	-39.43	.10	-.10
75.60	-41.46	-41.37	-41.54	.09	-.09
75.90	-44.40	-44.33	-44.46	.07	-.07
76.20	-40.29	-40.22	-40.35	.06	-.06
76.50	-43.42	-43.35	-43.49	.07	-.07
76.80	-42.80	-42.73	-42.86	.07	-.07
77.10	-43.29	-43.22	-43.35	.06	-.06
77.40	-43.88	-43.80	-43.95	.07	-.07
77.70	-41.21	-41.14	-41.27	.07	-.07
78.00	-43.67	-43.60	-43.75	.07	-.07

TABLE XIV (cont.)

78.30	-41.23	-41.16	-41.31	.07	-.07
78.60	-42.53	-42.45	-42.61	.08	-.08
78.90	-41.87	-41.79	-41.94	.07	-.07
79.20	-46.19	-46.13	-46.24	.06	-.06
79.50	-41.43	-41.36	-41.50	.07	-.07
79.80	-41.46	-41.37	-41.55	.09	-.09
80.10	-39.11	-39.01	-39.22	.10	-.10
80.40	-38.16	-38.05	-38.27	.11	-.11
80.70	-41.42	-41.33	-41.51	.09	-.09
81.00	-40.92	-40.83	-41.01	.09	-.09
81.30	-42.23	-42.13	-42.33	.10	-.10
81.60	-40.43	-40.34	-40.52	.09	-.09
81.90	-40.50	-40.44	-40.57	.06	-.06
82.20	-41.92	-41.84	-42.00	.08	-.08
82.50	-40.95	-40.87	-41.03	.08	-.08
82.80	-41.16	-41.09	-41.23	.07	-.07
83.10	-41.82	-41.74	-41.89	.07	-.07
83.40	-41.84	-41.78	-41.90	.06	-.06
83.70	-42.96	-42.90	-43.02	.06	-.06
84.00	-39.16	-39.05	-39.26	.11	-.11
84.30	-40.14	-39.97	-40.30	.17	-.16
84.60	-44.16	-43.97	-44.35	.19	-.19
84.90	-42.29	-42.12	-42.45	.16	-.16
85.20	-42.06	-41.95	-42.18	.12	-.12
85.50	-42.33	-42.24	-42.43	.10	-.09
85.80	-44.96	-44.86	-45.06	.10	-.10
86.10	-40.13	-40.07	-40.19	.06	-.06
86.40	-41.60	-41.54	-41.65	.06	-.06
86.70	-42.41	-42.36	-42.47	.06	-.06
87.00	-43.08	-43.03	-43.14	.06	-.06
87.30	-45.15	-45.08	-45.22	.07	-.07
87.60	-42.12	-42.04	-42.20	.08	-.08
87.90	-41.58	-41.52	-41.65	.06	-.06
88.20	-41.85	-41.70	-42.00	.15	-.15
88.50	-40.00	-39.83	-40.17	.17	-.17
88.80	-40.18	-40.01	-40.35	.17	-.17
89.10	-39.14	-38.97	-39.31	.17	-.17
89.40	-42.52	-42.36	-42.68	.16	-.16
89.70	-42.38	-42.23	-42.52	.14	-.14
90.00	-42.61	-42.47	-42.75	.14	-.14

LIST OF REFERENCES

1. Leoussis, G. S., Implementation of an Automated Millimeter-Wave Scalar Network Analyzer, Master's Thesis, Naval Postgraduate School, Monterey, California, December 1982.

2. Hughes Aircraft Company, Microwave Products Division, Millimeter-Wave Products 1985 Catalog, Hughes Aircraft Company, Microwave Products Division, Torrance, California, 1985.

3. Knorr, J. B., "Scattering Analysis of a Millimeter-Wave Scalar Network Analyzer," IEEE Transactions On Microwave Theory and Techniques, v. MTT-32, no. 2, pp. 183-190, February 1984.

4. Gatsos, E. D., Reflection and Insertion Loss Software Developments for an Automated Scalar Network Measurement System, Master's Thesis, Naval Postgraduate School, Monterey, California, June 1983.

5. M/A-COM Millimeter Products, Inc., Millimeter Wave Products, M/C-COM Baytron, Inc., Burlington, Massachusetts, 1985.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22304-6145	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943-5002	2
3.	Department Chairman, Code 62 Department of Electrical Engineering Naval Postgraduate School Monterey, California 93943	1
4.	Professor Jeffrey B. Knorr, Code 62KO Department of Electrical Engineering Naval Postgraduate School Monterey, California 93943	2
5.	Lieutenant David E. Falkner, USN 4012 Arthington Boulevard Indianapolis, Indiana 46226	2

220181
Thesis
F21556 Falkner
c.1 Improving the performance of a millimeter-wave scalar network analyzer.